NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

COHERENCE STUDY OF GEOMAGNETIC FLUCTUATIONS
IN FREQUENCY RANGE .04 - 0.6 HZ
BETWEEN REMOTE LAND SITES

by

Stephen John Anthony

December 1983

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Coherence Study of Geomagnetic Fluctuations in Frequency Range .04 - 0.6 Hz Between Remote Land Sites

by

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ABSTRACT

Fluctuations in the geomagnetic field were measured by three orthogonally mounted coil sensors at two land sites separated by 40 km. Computer generated voltage vs time and magnetic field vs time plots failed to reveal the presence of dominant micropulsations. A coherence study between the two sites revealed coherence values of 0.6 - 0.8 in the frequency range 0.04 - 0.6 Hz. This is compared to a coherence study completed at the Naval Air Development Center, Warminster, Pennsylvania, between land sites 24.8 km apart. The NADC coherence values are lower (0.3 - 0.6).

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I. INTRODUCTION

This thesis is part of an ongoing effort at the Naval Postgraduate School to analyze ULF geomagnetic noise and micropulsations. These variations in the geomagnetic field are of interest both from a geophysical and a military viewpoint. Applications of interest to the Navy are in the areas of magnetic detection of submarines, mine warfare and communications systems.

The specific objectives of this study were to install and operate a simultaneous data collection system at two separated land sites, to modify and adapt previously developed software for data analysis and to obtain spectral coherences between the two sites for background noise and/or micropulsations.

A coherence study of background noise with background noise, of micropulsation with micropulsation and of background noise with micropulsation between the two sites should further the understanding of the types and extent of the sources that produce these fluctuations.

The data collection sites were separated by a distance of 40 km (see Appendix A). One site was at La Mesa Village, near the Naval Postgraduate School campus, while the other was at the Chew's Ridge fire lookout. The latter was chosen for its remoteness from the local power grid.

II. BACKGROUND

A. MICROPULSATIONS

The frequency spectrum of the geomagnetic field observed on or near the earth's surface has a number of well defined peaks, corresponding to categories of regular geomagnetic micropulsations, as shown in Figure 2.1. These micropulsations are designated as Pc1, Pc2, ... Pc5.

Another category of micropulsations encountered is irregular pulsations. Unlike regular Pc micropulsations, which have relatively well defined frequencies, the Pi micropulsation consists of a spectral band of noise.

The source of these micropulsations appears to be magneto-hydrodynamic resonances in the earth's magnetosphere (Pc2 - Pc5), ion cyclotron wave-particle interaction in the magnetosphere (Pc1) and ionospheric currents perturbed by conductivity variations (Pi). References 1 and 2 give more detailed explanations of these mechanisms. Micropulsations are classified as follows:

1. Pc1: (0.2 - 5 Hz frequency)

Known as "Pearls", these micropulsations are generated by the cyclotron instability of energetic protons. They have been positively correlated with solar disturbances and occur during daylight hours in the auroral zone and

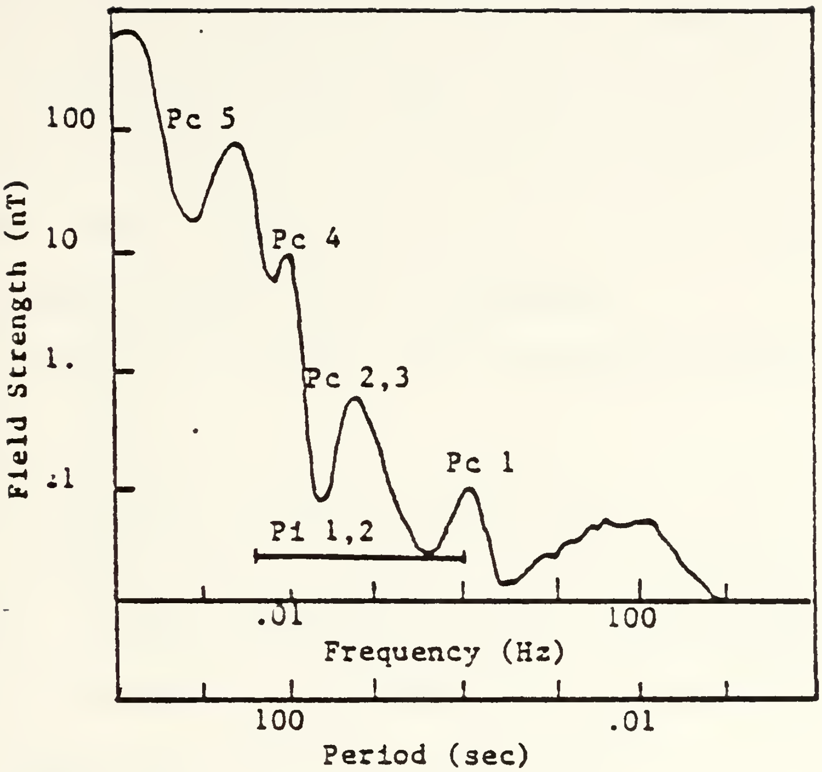

Figure 2.1 Field Strength of Micropulsations.

during night and early morning hours in the midlatitudes. Typical amplitudes are 0.05 - 0.1 nanotesla.

2. Pc2: (0.1 - 0.2 Hz frequency)

This is a diurnal phenomenon that shows some positive correlations with solar activity and the seasons. They usually decrease in their period as magnetic activity increases. Their average amplitude is 0.1 - 1 nanotesla.

3. Pc3: (0.022 - 0.1 Hz frequency)

These are similar to Pc2 pulsations except for the frequency range.

4. Pc4: (6.7 - 22 mHz frequency)

Sunspot activity appears to have an effect on Pc4 pulsations. Their frequency varies with the season and they have an average amplitude of 5 - 10 nanotesla.

5. Pc5: (1.7 - 6.7 mHz frequency)

These large scale pulsations occur during morning and evening with amplitudes of 10 - 100 nanotesla. Their duration shows a strong geomagnetic latitude dependence.

6. Pi1: (0.025 - 1 Hz frequency)

These pulsations usually occur at night and early morning and vary in intensity from 0.01 - 0.1 nanotesla. They demonstrate a positive correlation with auroral disturbances.

7. Pi2: (6.7 - 25 mHz frequency)

The amplitude of these pulsations ranges from 1 - 5 nanotesla. They usually occur during early morning hours but may continue throughout the night. The frequencies of these pulsations increase with increasing magnetic activity.

Geomagnetic micropulsations can be distinguished from the general noise background of the geomagnetic field. The micropulsation events rise out of the ever present background activity, reach an amplitude that can be large in comparison to the background level, and then finally disappear into the background. The Pc4 and Pc5 pulsations can last several hours. However, the Pc1 - Pc3 and Pi micropulsations have a maximum duration of approximately one hour but may last only a few minutes.

B. GEOMAGNETIC BACKGROUND NOISE

It has been speculated that the primary source of the geomagnetic background noise is fluctuations in the interplanetary magnetic field [Ref. 3]. If so, a source of such large spatial extent implies that the amplitude of the background noise may be less variable over the surface of the earth than the more locally generated micropulsations, and one could expect considerable spatial coherency of the background noise over the earth's surface.

David and Heirtzler [Ref. 4] studied the coherence of geomagnetic variations between two stations up to 550 km apart. The geomagnetic variations were separated into a background noise component and a micropulsation component. When two different micropulsation types occurred simultaneously, they were found to be incoherent with one another and with the background noise. It would thus appear that independent generation mechanisms exist for the background noise component and for micropulsations of different types. Also, the background component showed association with the solar quiet day magnetic variation (Sq). In particular, the spectrum amplitude of the background component increased as the strength of Sq increased.

III. DATA COLLECTION SYSTEM

A. EQUIPMENT DESCRIPTION

The system used at both the Chew's Ridge and La Mesa Village sites is shown in Figure 3.1. The major components are:

(1) Coil sensors

(2) Preamplifiers

(3) Signal conditioner

(4) Pulse Code Modulation (PCM) encoder

(5) WWV radio receiver

(6) Tape recorder

(7) Power source

For a geographical description of the two sites, see Appendix A.

1. Coil Sensors

Each coil is continuously wound with 5460 turns of 18 gauge copper magnet wire. It has an internal resistance of 9.31 Henries. At each site, the three coils were mounted orthogonally, with the x coil oriented towards magnetic north, the y coil towards magnetic east and the z coil vertically downwards.

2. Preamplifiers

The preamplifiers are model 13-10A low noise amplifiers manufactured by Dr. Allen Phillips of SRI

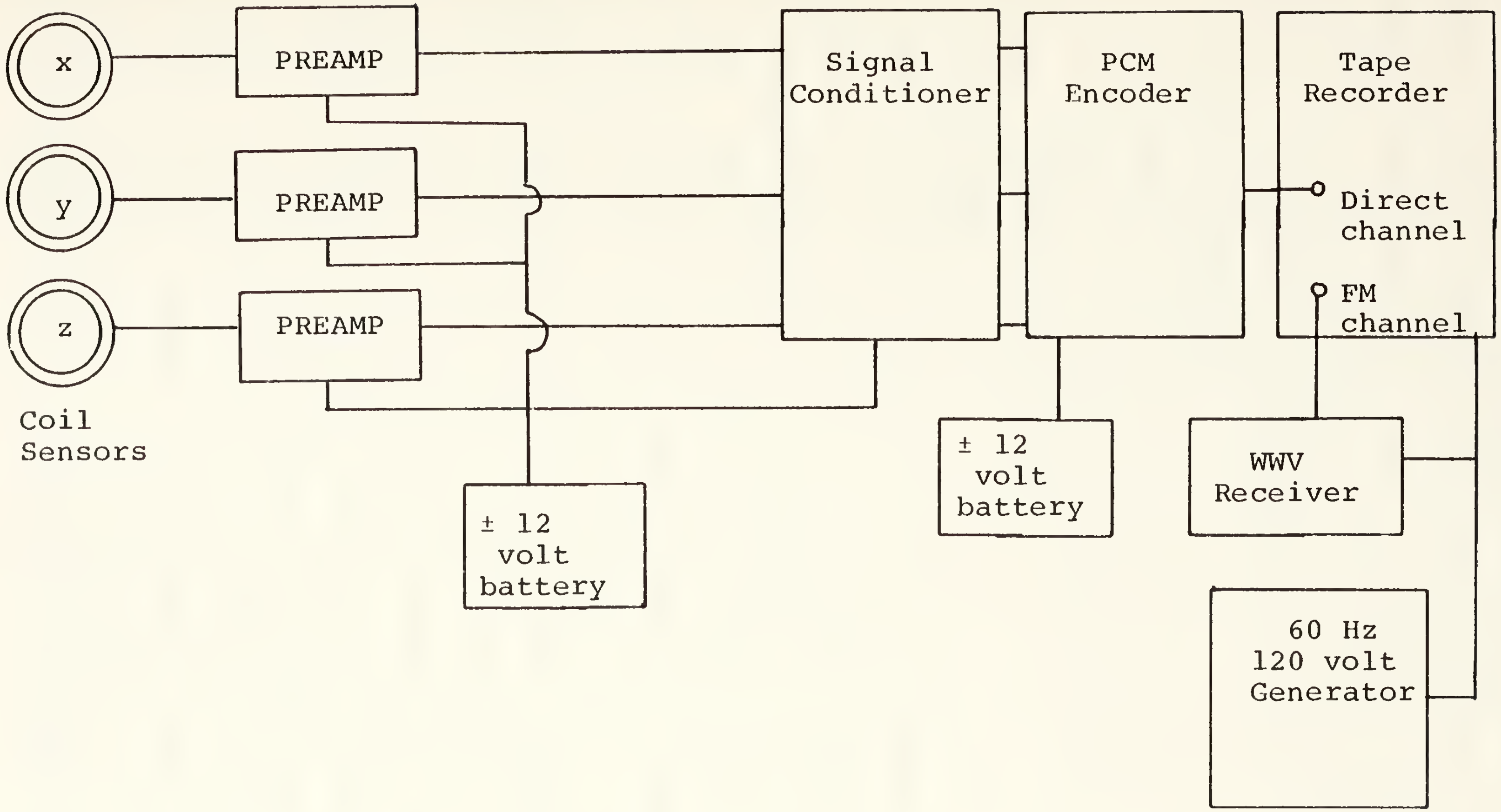

Figure 3.1 Block Diagram of Data Collection System.

International. The overall power gain is 60 dB for inputs less than 2.5 mV. A final stage low pass filter which provides a sharp cutoff at 20 Hz is provided. Each preamplifier has a DC offset potentiometer which must be adjusted to provide the correct zero-level at the output.

3. Signal Conditioner

The signal conditioner receives the analog signals from the preamplifiers, amplifies them by 30 dB and limits them to an amplitude of 7.5 volts.

4. PCM Encoder

The pulse code modulation (PCM) was designed and manufactured by Dr. Robert Lowe of Lowecom Incorporated and of the Scripps Institute of Oceanography in La Jolla, California. The encoder features 15 channel analog input capability with selectable sample rates of 2^n samples per second, where n is an integer value of 3 to 7. For the purposes of this thesis only 3 of the input channels were utilized (1, 2 and 3 for the x, y and z channels, respectively), and a sample rate of 64 samples per second was chosen to ensure adequate measurement of frequencies below 0.1 Hz. The encoder samples the analog signal from each channel at a rate of 64 Hz and assigns a pulse coded digital word with a decimal value between 0 and 4096 to each sample, corresponding to an amplitude of -5 to +5 volts. The output data is organized into frames, each

frame headed by a synch code word which is followed sequentially by the pulse coded samples from input channels 1 through 15. The synch code word is a pulse coded digital word with a decimal value of between 0 and 4096. This word is preselected and hardwired on the encoder circuit board. Reference F explains the PCM system in more detail.

5. WWV Radio Receiver

In order to ensure that the data from the two sites was analyzed simultaneously, an R-1051 B/URR radio receiver was used to monitor the WWV Universal Time broadcast at 20 MHz at each site. The broadcast gives the Universal Time at each minute by voice with each second marked by a tone.

6. Tape Recorder

Hewlett-Packard HP3964A/3968A tape recorders were used to record the PCM data and WWV broadcast on analog magnetic tape. The output from the PCM encoder was recorded on a direct channel (100 - 16000 Hz frequency response) and the WWV time signal was recorded on an FM channel.

7. Power Source

At the Chew's Ridge site the power source used was a 3500 watt, 60 Hz, 120 volt, gasoline powered, portable generator. The separation between the sensor coils and instrumentation was about 100 feet, and between the sensor coils and portable generator approximately 250 feet. Commercial 60 Hz power was available at the La Mesa Village site.

The preamplifiers, signal conditioners and PCM encoders were powered by rechargeable 18 amp-hour batteries (plus and minus 12 volts and ground).

B. PCM TO DIGITAL CONVERSION

The PCM data recorded on analog tape is played back into a PCM decoder which converts it to digital data. The digital data is recorded in 9-track, 800 bits per inch computer tape for subsequent analysis on the IBM 3033 mainframe computer. Appendix B contains a step-by-step procedure for the decoding process.

By listening to the FM channel carrying the WWV time signal over a speaker, the point on the analog PCM tape where it is desired to begin and stop the decoding process may be precisely determined. In this manner it is possible to obtain time synchronized digital computer tapes of data from the two sites.

IV. COMPUTER SOFTWARE

The computer programs used to analyze the data are written in Fortran IV programming language and are briefly discussed below. These programs are listed in Appendices C - G.

A. PROGRAM VOLTR

The VOLTR program reads data from a digital computer tape and generates a voltage vs time plot for each orthogonal axis. The data is read from the tape in blocks of 8192 frames (128 seconds) by the subroutine RD. This data, which is in integer form between 0 to 4096, is then normalized to represent voltages between ± 5 volts. The amount of data plotted is an integer increment of 128 seconds, the integer being from 1 to 8 and specified by the user.

B. PROGRAM VODIG

This program applies a 144 point double running average and a .04 - 0.6 Hz digital filter to the rough voltage and generates filtered voltage vs time plots for each axis. The digital filter simulates the pass band of an AN/SQ-81 magnetometer and was developed by Mike Huete of the Naval Postgraduate School. Reference 5 explains the filter in detail. The double running average smooths out any large noise "spikes" that may cause an unnatural oscillatory

response in the digital filters. It also acts as a low pass filter, removing frequencies greater than approximately 1 Hz.

C. MASS STORAGE PROGRAM

In order to compare simultaneous data from two different computer tapes, the data is read from one tape (La Mesa Village), normalized to voltage values and stored in the IBM 3033 Mass Storage System, where it is available for future recall.

D. PROGRAM MAGFLD

This program generates magnetic field vs time plots. The digital data is read from the computer tape and normalized to voltage values. A Fourier transform is performed on the data to enter frequency space. At this point the system transfer function, which converts the data from voltage to magnetic field values, is applied. References 6 and 8 detail the procedures used to determine the transfer function for each coil sensor-amplifier subsystem. After the transfer function has been applied, a second Fourier transform is performed to return the data to time space. A 144 point double running average is then applied to the magnetic field data to remove frequencies above about 1 Hz.

B. PROGRAM COHER

This program calculates the spectral coherence of the total field between the two sites and the power spectral densities of the total field at each site. The La Mesa Village data previously stored in the Mass Storage System is recalled, the corresponding Chew's Ridge data is read from a computer tape, and the two data sets manipulated simultaneously.

Referring to Figure 4.1, the total field was calculated as

$$\text{total field} = x\cos\theta_d + z\sin\theta_d$$

where θ_d is the magnetic dip angle, which in the Monterey area is 60°.

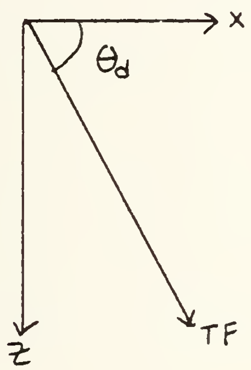

Figure 4.1 Total Field Diagram

The coherence between two signals a(t) and b(t) is

$$\text{coherence} = \frac{a(t)\circ b(t)}{\sqrt{a(t)\circ a(t)}\ \sqrt{b(t)\circ b(t)}} = \frac{A(F)B^*(F)}{\sqrt{a(F)A^*(F)}\ \sqrt{B(F)B^*(F)}}$$

where '$\circ$' indicates the correlation separation, '*' indicates

the complex conjugate is taken and $A(F)$ and $B(F)$ are the Fourier transforms of $a(t)$ and $b(t)$, respectively.

In the program, a Fourier transform of the data into frequency space was performed and an average of 20 blocks of data (128 seconds per block) was taken to obtain the final coherence values.

V. TESTING OF PCM SYSTEM AND SOFTWARE

In order to ensure that the PCM system and VOLTR program faithfully reproduced the input signals, sinusoidal, triangular and square waves were input to the PCM encoder by a Wavetek signal generator, as shown in Figure 5.1, and the PCM signal recorded on analog tape. The signal generator output was also monitored by a chart recorder and voltmeter. The analog tape was then decoded and voltage vs time plots were generated by the VOLTR program.

Table 5.1 shows the relationship between the amplitude of the signal generator output and the amplitude of the VOLTR plots (Figure 5.2) at various frequencies for the sinusoidal signal.

As can be seen from Table 5.1, the error between the chart record and the computer plot is less than two percent. Similar results were obtained for the triangular and square wave on all three channels.

Extensive testing of the Mass Storage program, and the digital filter algorithm employed in the VODIG program, is documented in References [6] and [7], respectively.

The program COHER was tested by analyzing a section of data against itself. Data from a computer tape was read into the mass storage system by the Mass Storage program. The same section of data was read from the tape by

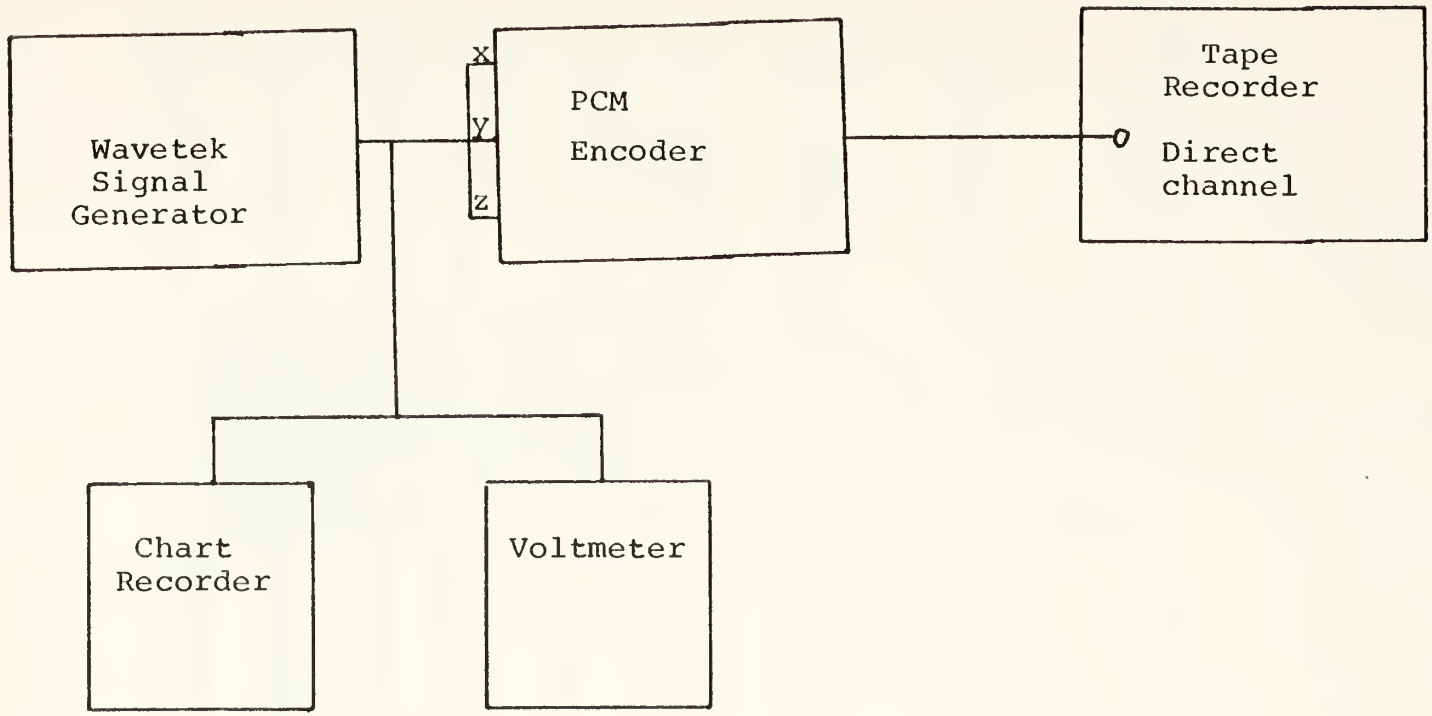

Figure 5.1 Block Diagram of Test System.

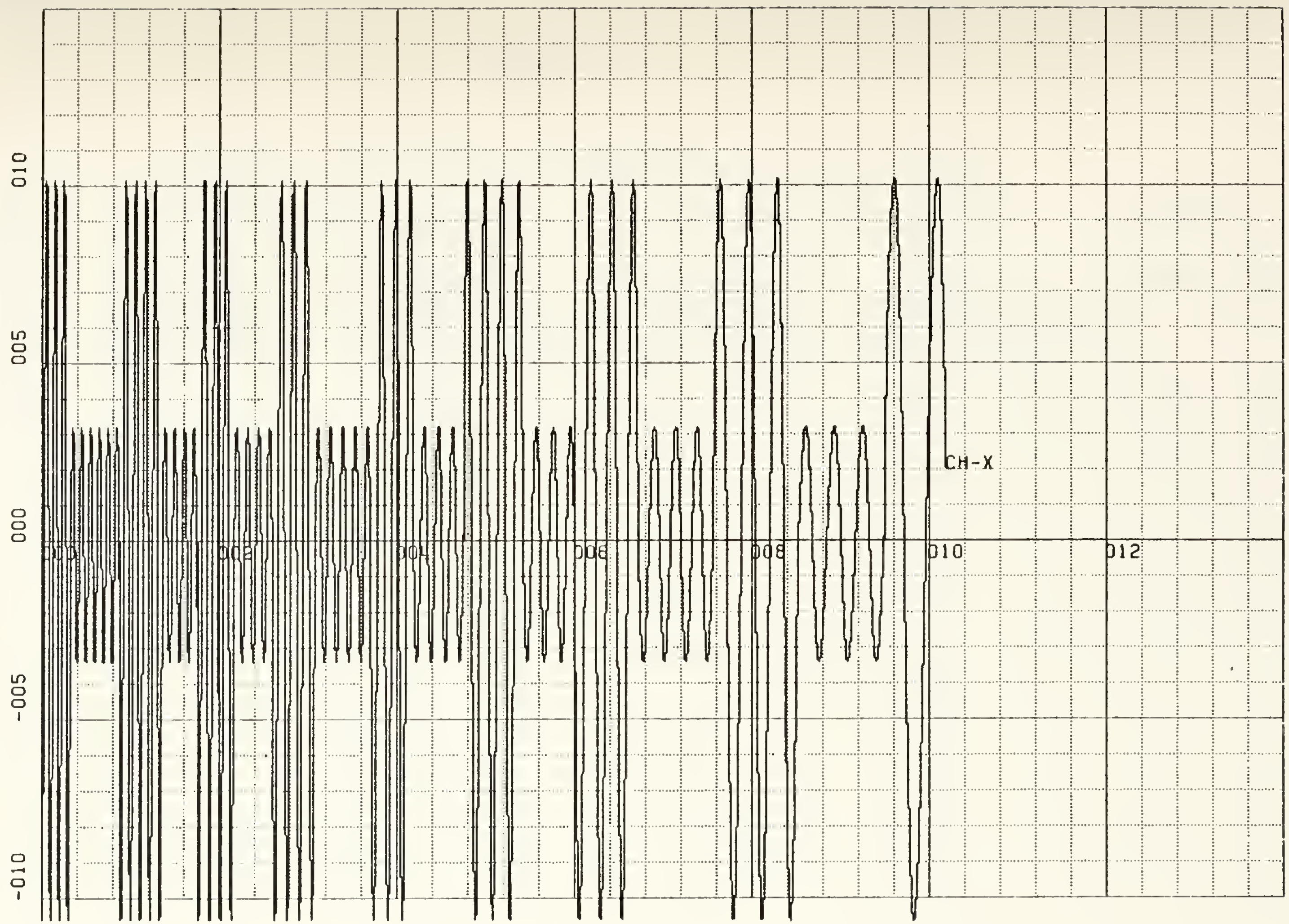

Figure 5.2 Test Voltage, Voltage (0.5 volts/inch) vs Time (200 seconds/inch).

TABLE 5.1

MEASURED AND COMPUTER GENERATED VOLTAGE VALUES

Freq (Hz)	Chart Record (volts)		Computer Plot volts		Error %	
	Large Amplitude Oscillations	Small Amplitude Oscillations	Large Amplitude Oscillations	Small Amplitude Oscillations	Large	Small
0.10	2.10 ± .01	0.67 ± .01	2.08 ± .01	0.66 ± .01	1.0	1.5
0.09	2.09	0.67	2.08	0.66	0.5	1.5
0.08	2.09	0.67	2.08	0.66	0.5	1.5
0.07	2.09	0.67	2.08	0.66	0.5	1.5
0.06	2.09	0.67	2.08	0.66	0.5	1.5
0.05	2.10	0.67	2.08	0.66	1.0	1.5
0.04	2.10	0.67	2.08	0.66	1.0	1.5
0.03	2.10	0.67	2.08	0.66	1.0	1.5
0.02	2.11	0.67	2.08	0.66	1.4	1.5
0.01	2.11	0.67	2.08	0.66	1.4	1.5

the COHER program and analyzed with the data recalled from mass storage. The COHER program generated a coherence vs frequency of 1 as expected (Figure 5.3).

Reference 8 mentioned the presence of "cross-talk" between the channels of the PCM encoder. This was noticed on computer generated plots on a channel whose input jack was left open while making measurements at a field site. To test for "cross-talk", a signal from the Wavetek signal generator was fed into all three channels of the PCM encoder, as in Figure 5.1. .One of the channels was disconnected from the Wavetek and the input jack left open. Then the input jack was grounded, and then finally the Wavetek signal was reconnected. Figure 5.4 is a rough voltage vs time plot for the sequence. It can be seen that while the input jack was open a signal did appear on the channel but disappeared while the input jack was grounded. The "cross-talk" mentioned in Reference 8 was actually the open input jack acting as a "pickup" antenna.

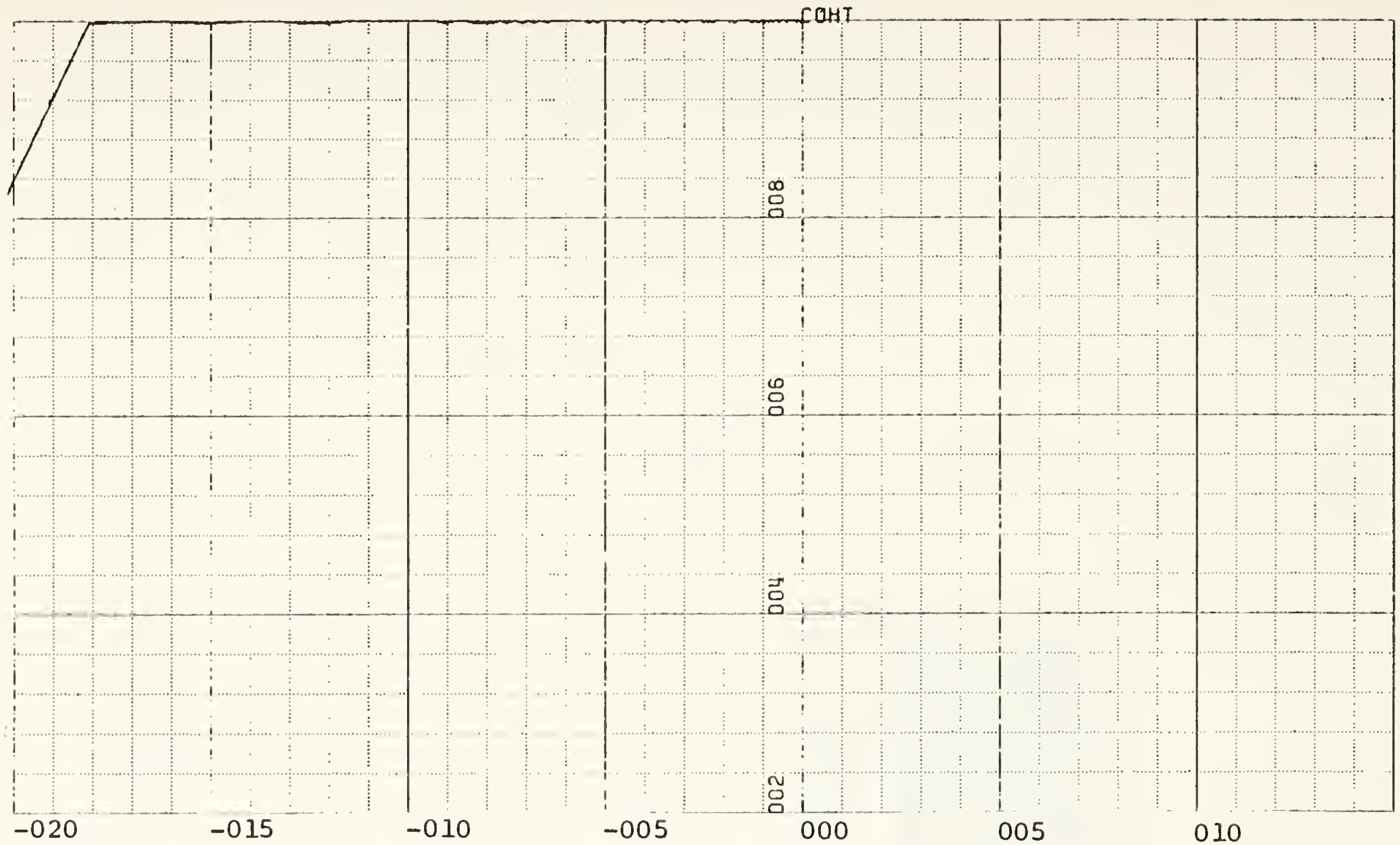

Figure 5.3 Coherence Test, Coherence (0.2 units/inch) vs Log Frequency (0.5 log Hz/inch).

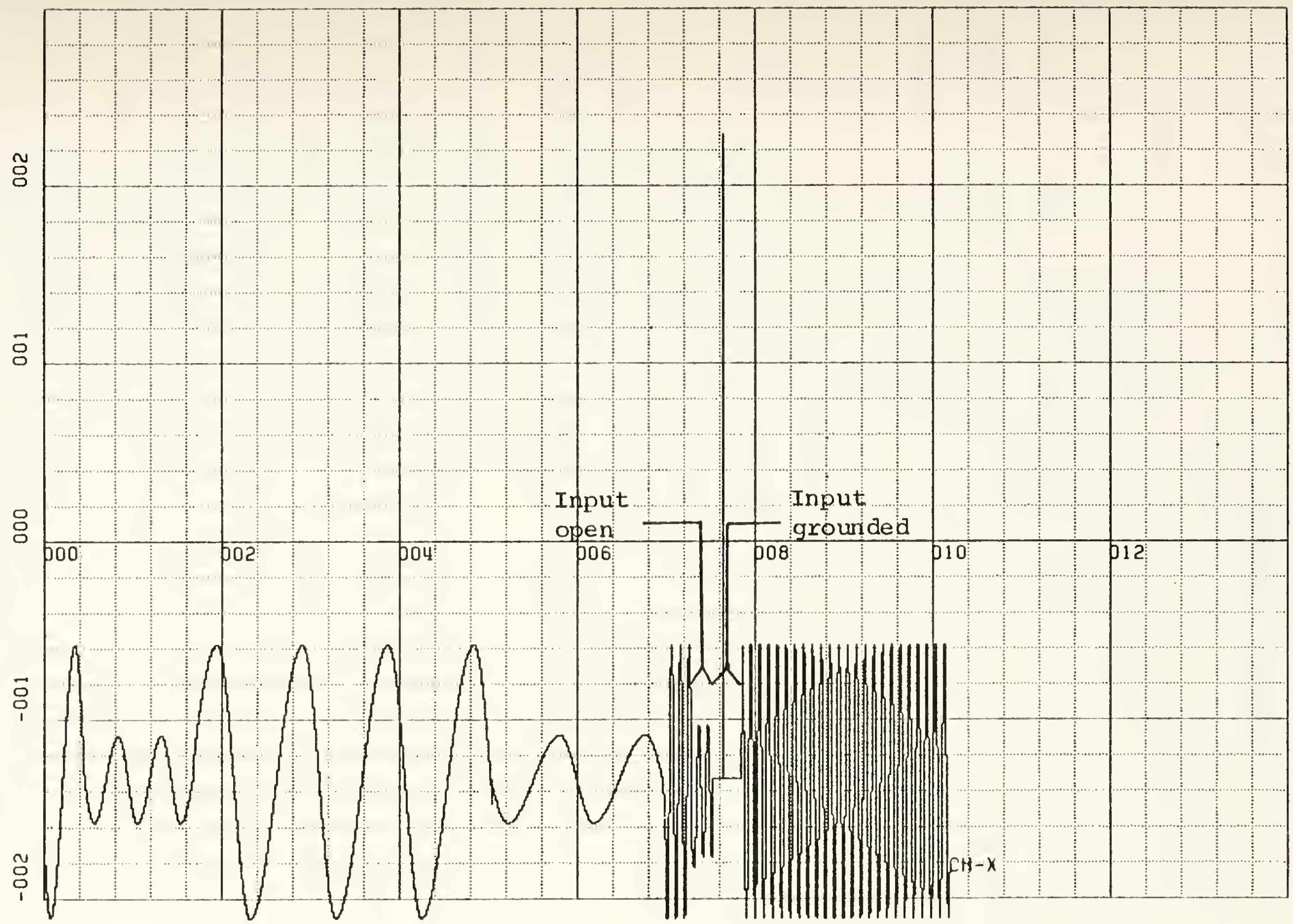

Figure 5.4 Test Voltage, Voltage (1 volts/inch) vs Time (200 seconds/ inch).

VI. EXPERIMENTAL RESULTS

Data was taken on 4 August 1983 between 1300 and 1845 local time. Beginning and ending the recording of the analog tapes was coordinated between the two sites over PRC-77 radios. Since it proved difficult to communicate between the two sites directly (because of intervening hills), a person using a radio with a large whip antenna at the Naval Postgraduate School directed the simultaneous starting and ending of data recording at the two sites.

On the voltage and magnetic field plots, the units labeled on the vertical scale are arbitrary and only the peak-to-peak variations should be considered.

A. ROUGH VOLTAGE PLOTS

Figures 6.1 - 6.6 show the rough voltage plots for the La Mesa Village site. These signals are totally obscured by 60 Hz noise. Figures 6.7 - 6.12 show the Chew's Ridge rough voltage plots. Here the 60 Hz noise is a site as remote as Chew's Ridge (to escape the 60 Hz power grid) is thus justified.

B. FILTERED VOLTAGE PLOTS

Figures 6.13 - 6.30 show typical filtered voltage vs time plots for both sites. Visual inspection failed to

reveal the presence of any large amplitude micropulsations or of any clear one-to-one correspondence in simultaneous sections of data.

C. MAGNETIC FIELD PLOTS

Figures 6.31 - 6.45 show typical magnetic field vs time plots for both sites. Magnetic field variations at the La Mesa site are approximately one nanotesla; variations at the Chew's Ridge site are slightly greater, 2 - 4 nanotesla.

D. COHERENCE PLOTS

Figures 6.46 - 6.57 show coherence vs frequency plots for individual axes and for the total field. The coherence generally has values between 0.6 - 0.8 indicating a moderate degree of commonality in the geomagnetic variations at the two sites.

These coherence plots can be compared with coherence vs frequency plots generated from background geomagnetic variation data taken at the Naval Air Development Center in 1979. The separation between the NADC data collection sites was 24.8 km. Figures 6.58 - 6.60 show these plots. In general, the coherence values from the NADC data are less than the coherence values found in our measurements. However, the amplitudes of geomagnetic variations are

probably influenced by factors such as the state of the ionosphere and magnetosphere and the stage of the solar cycle.

The NADC data was averaged over a period of two hours while our data was averaged over a period of 40 minutes.

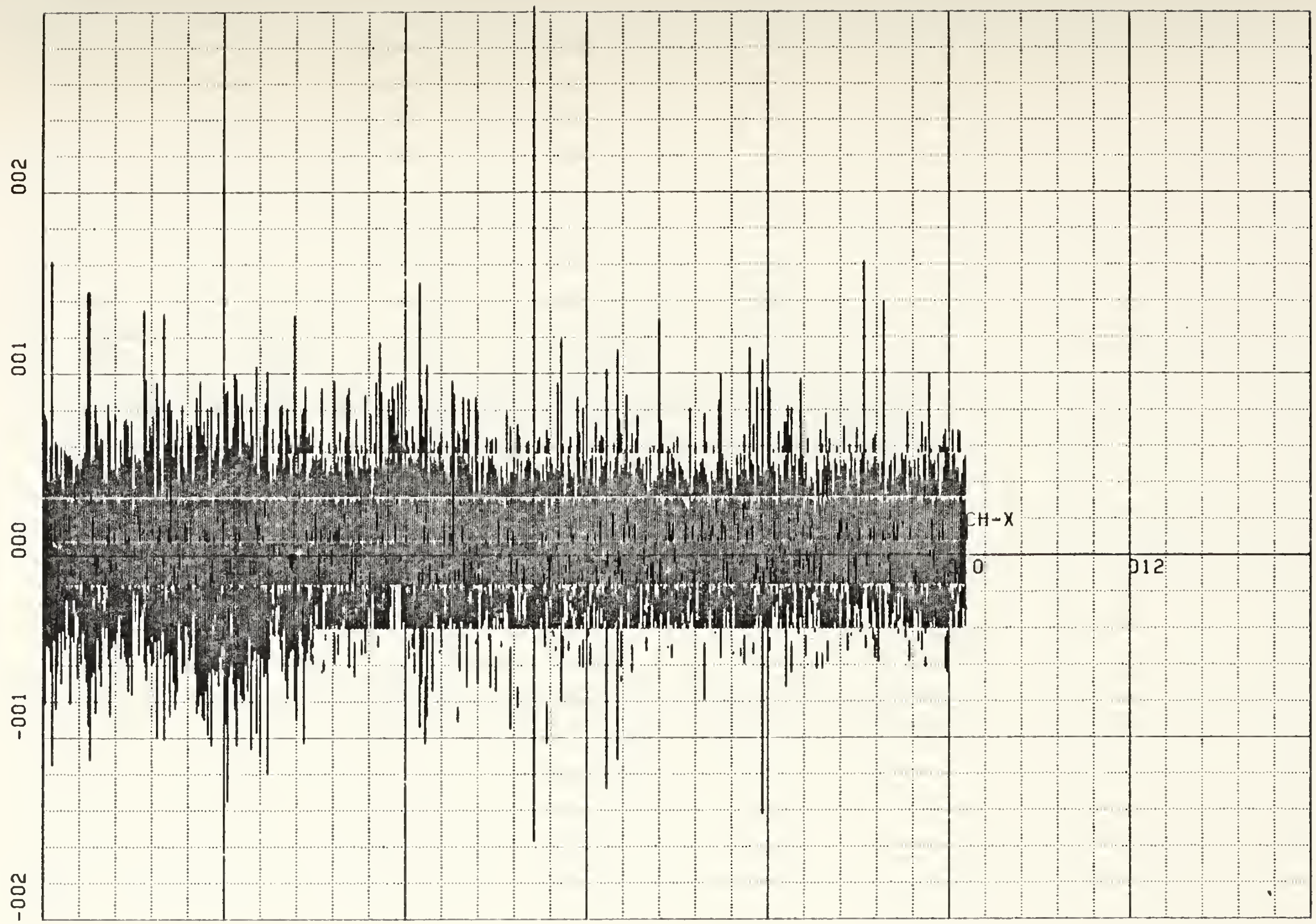

Figure 6.1 X Coil Voltage

La Mesa Village, 1359 - 1416 Local

Voltage (1 volt/inch) vs Time (200 seconds/inch).

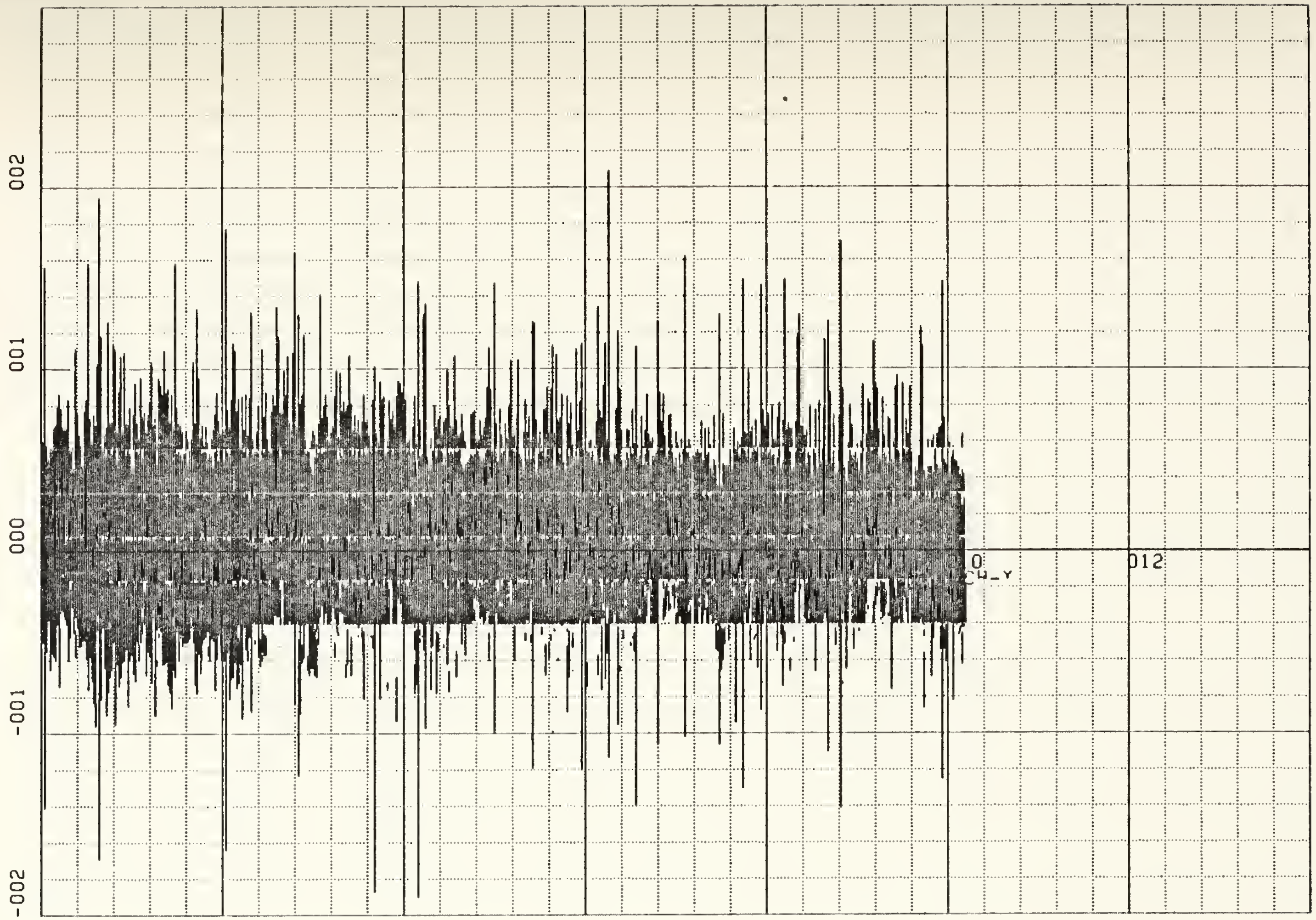

Figure 6.2 Y Coil Voltage

La Mesa Village, 1359 - 1416 Local

Voltage (1 volt/inch) vs Time (200 seconds/inch).

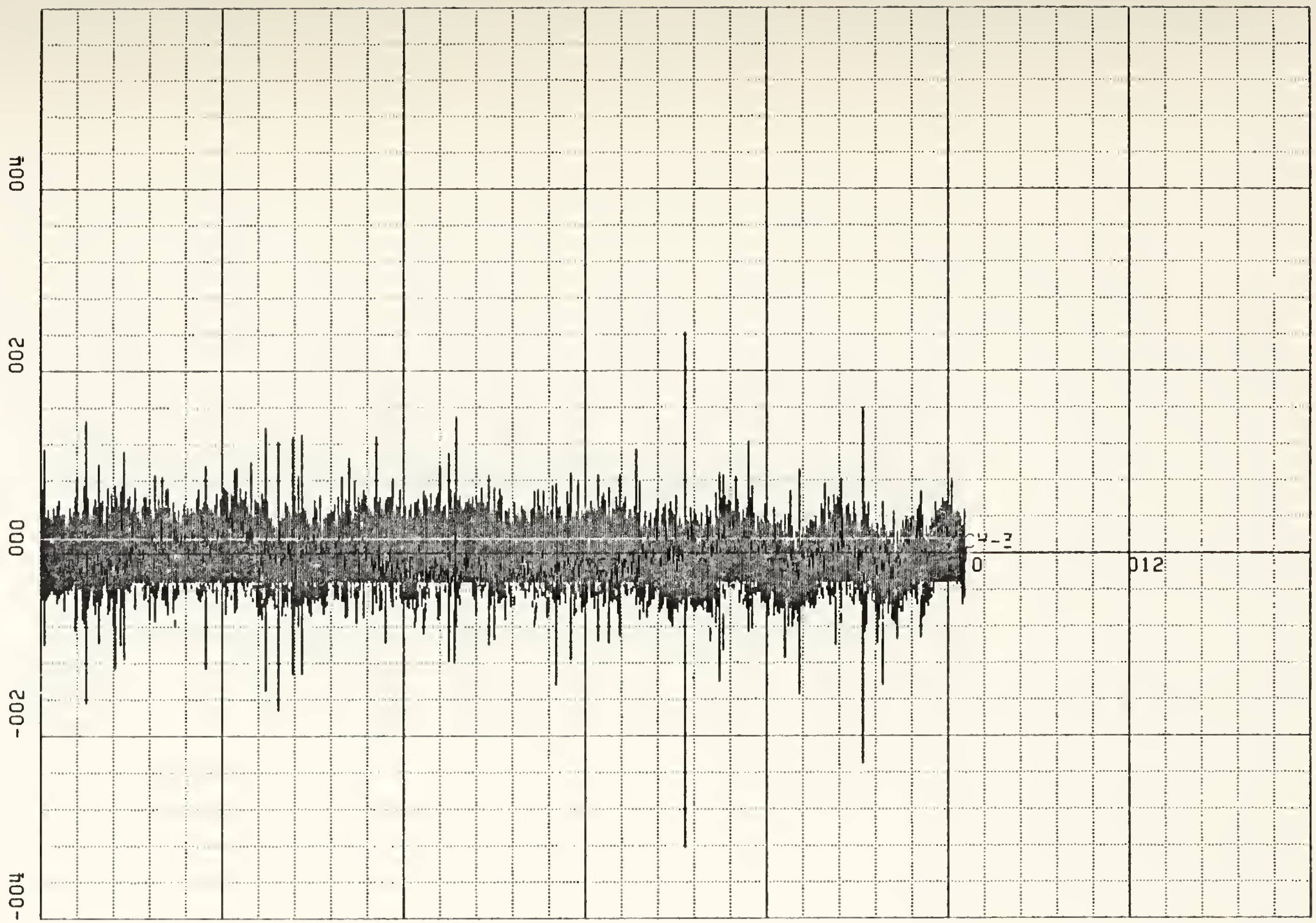

Figure 6.3 Z Coil Voltage

La Mesa Village, 1359 - 1416 Local

Voltage (2 volts/inch) vs Time (200 seconds/inch).

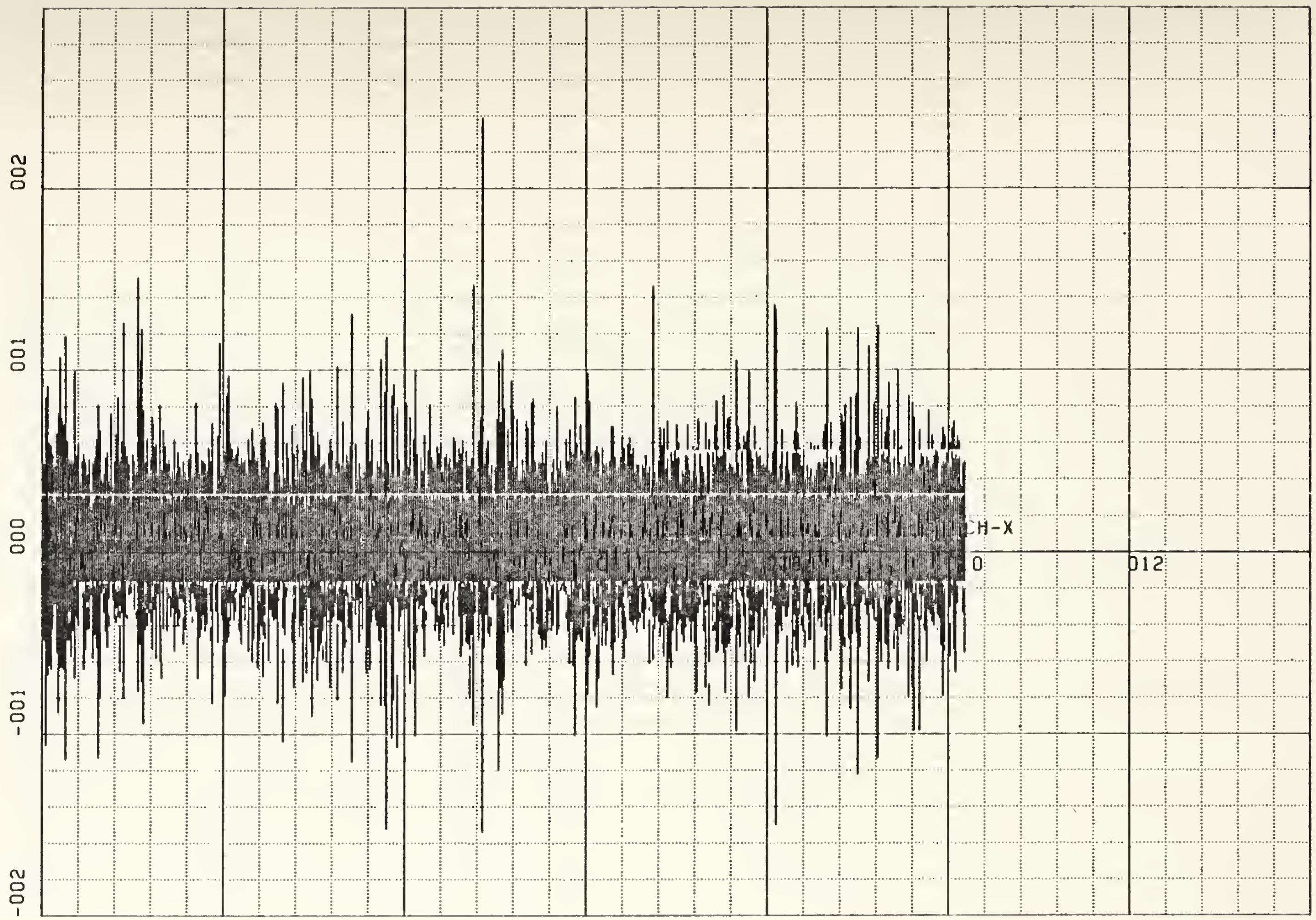

Figure 6.4 X Coil Voltage

La Mesa Village, 1500 - 1517 Local

Voltage (1 volt/inch) vs Time (200 seconds/inch).

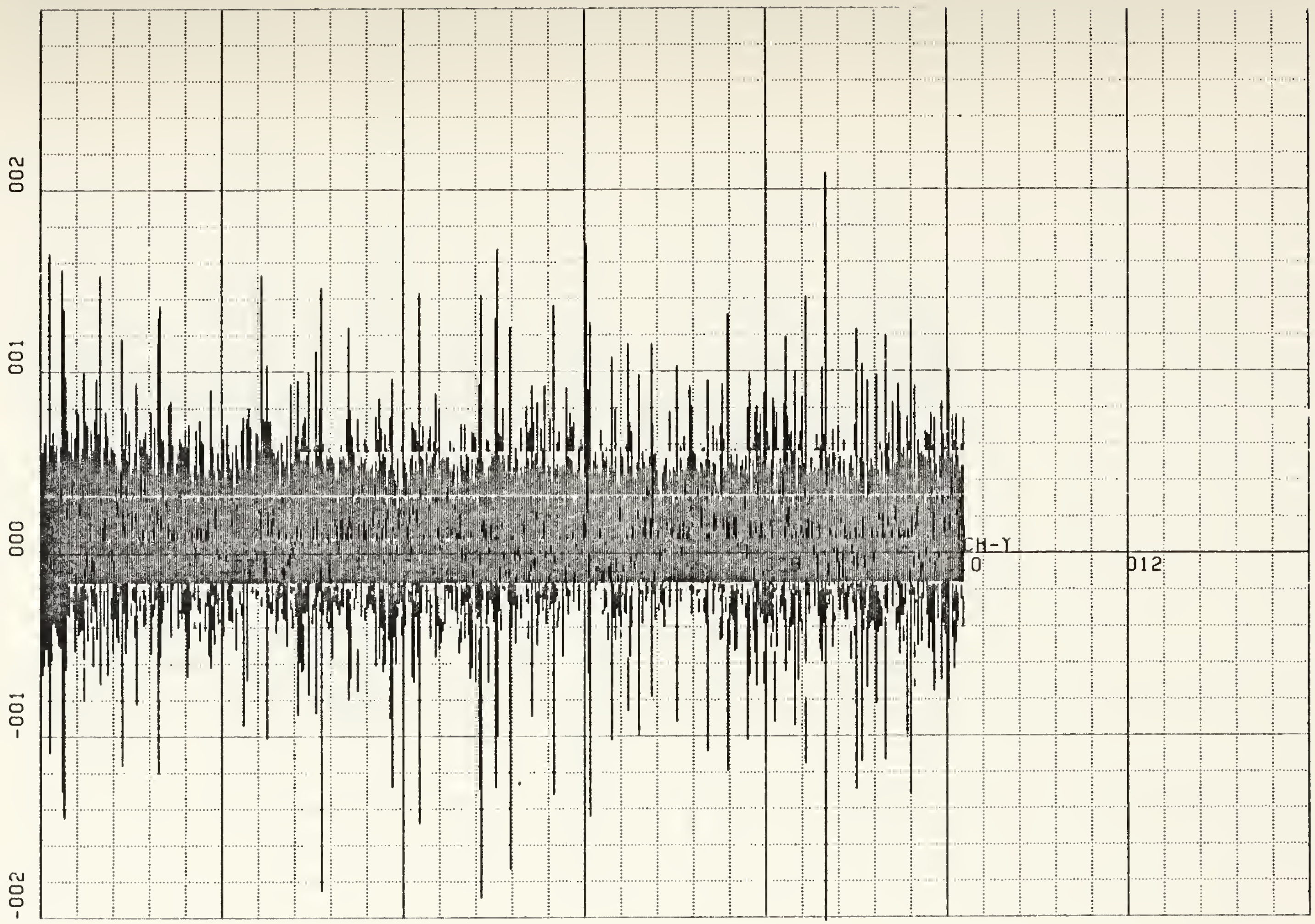

Figure 6.5 Y Coil Voltage

La Mesa Village, 1500 - 1517 Local

Voltage (1 volt/inch) vs Time (200 seconds/inch).

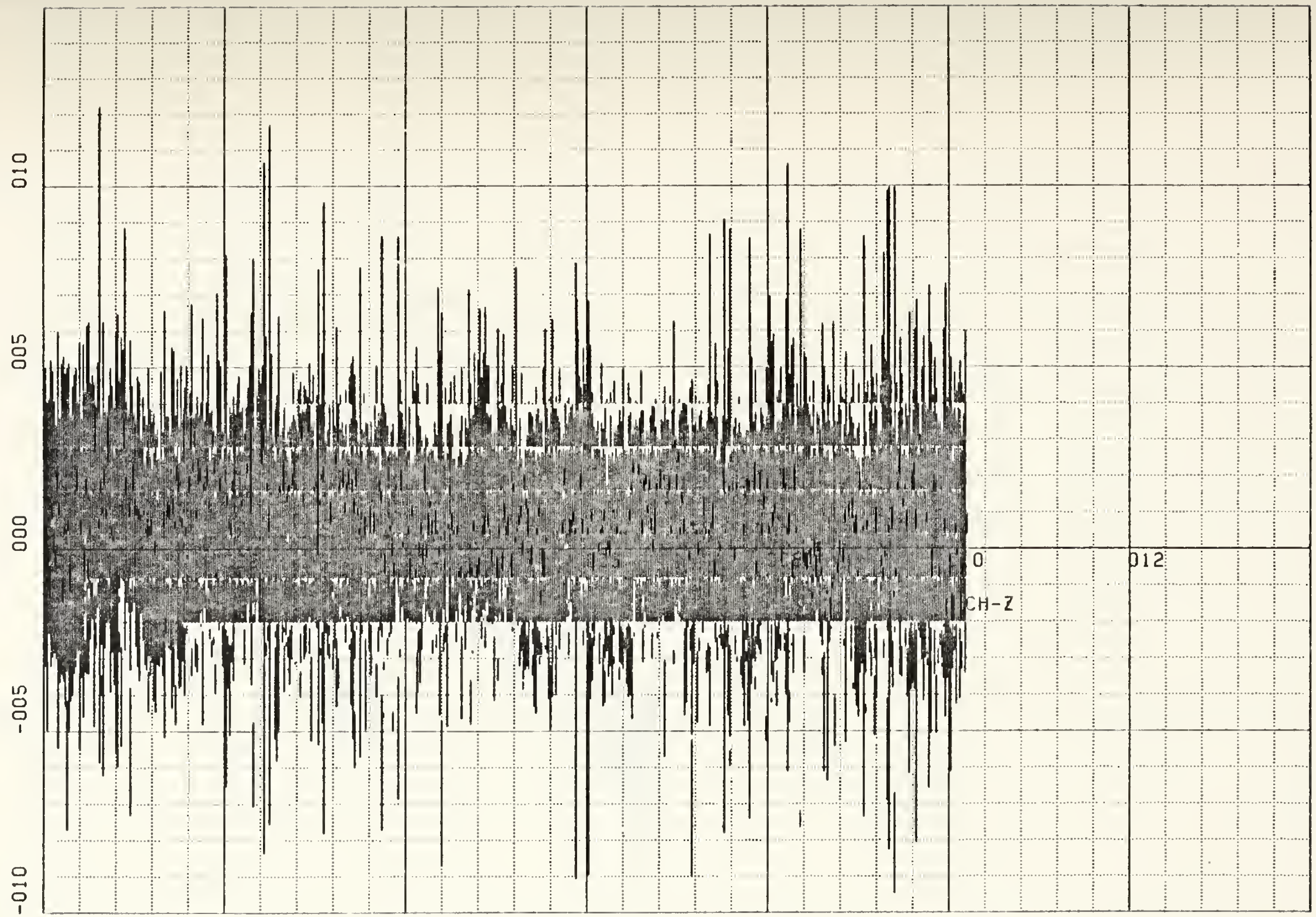

Figure 6.6 Z Coil Voltage

La Mesa Village, 1500 - 1517 Local

Voltage (0.5 volts/inch) vs Time (200 seconds/inch).

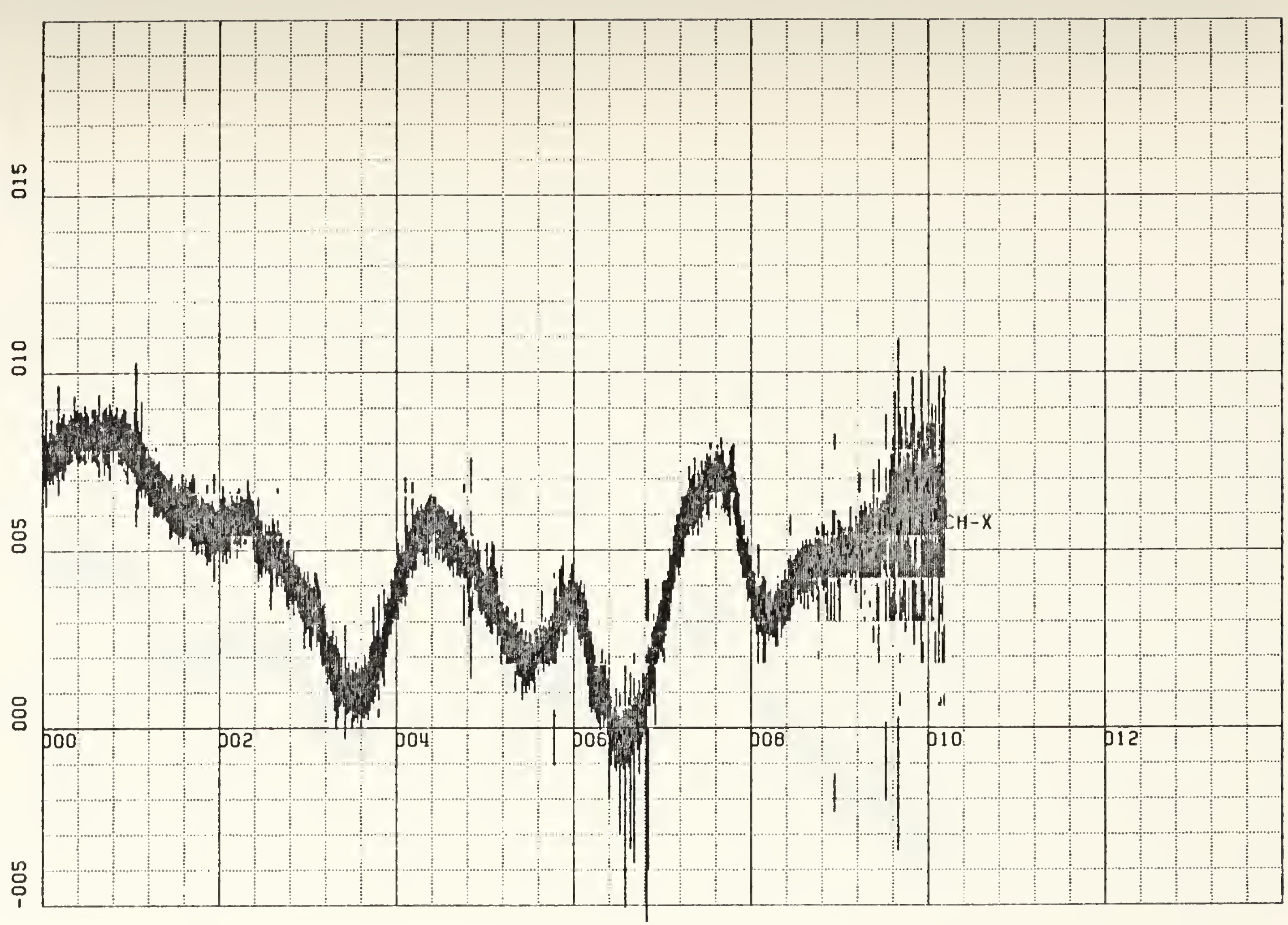

Figure 6.7 X Coil Voltage

Chew's Ridge, 1500 - 1517 Local

Voltage (0.5 volts/inch) vs Time (200 seconds/inch).

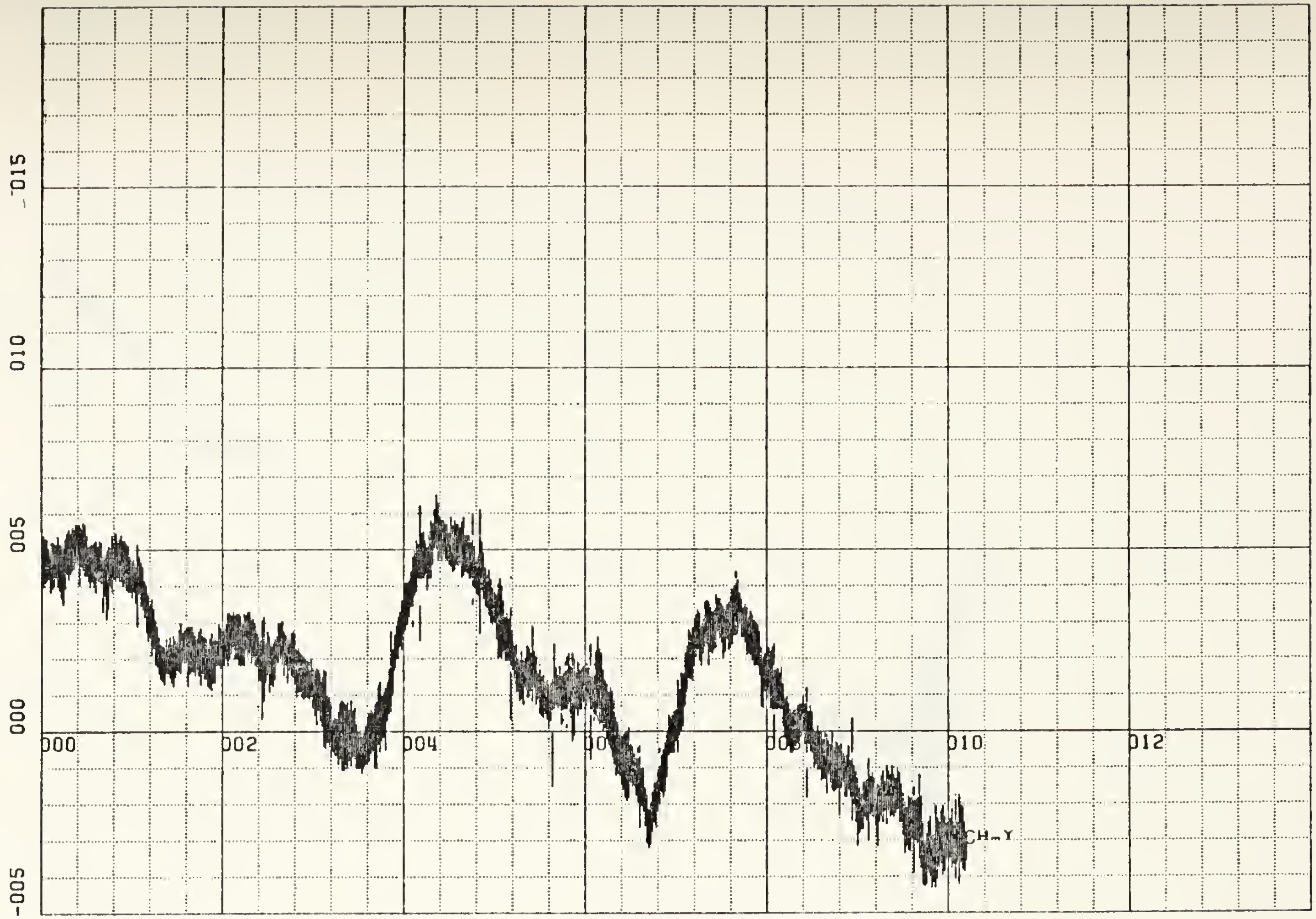

Figure 6.8 Y Coil Voltage

Chew's Ridge, 1500 - 1517 Local

Voltage (0.5 volts/inch) vs Time (200 seconds/inch).

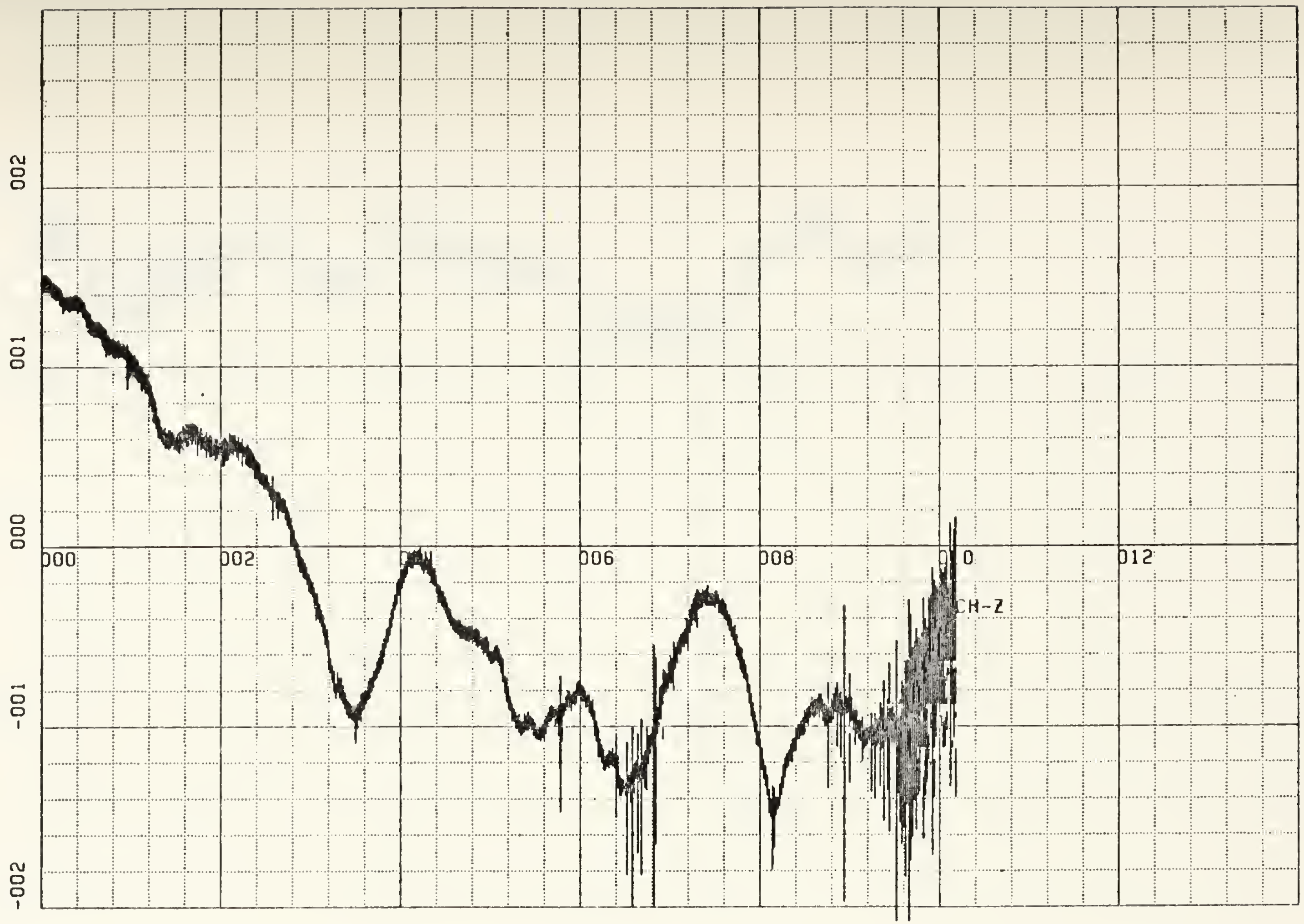

Figure 6.9 Z Coil Voltage

Chew's Ridge, 1500 - 1517 Local

Voltage (1 volt/inch) vs Time (200 seconds/inch).

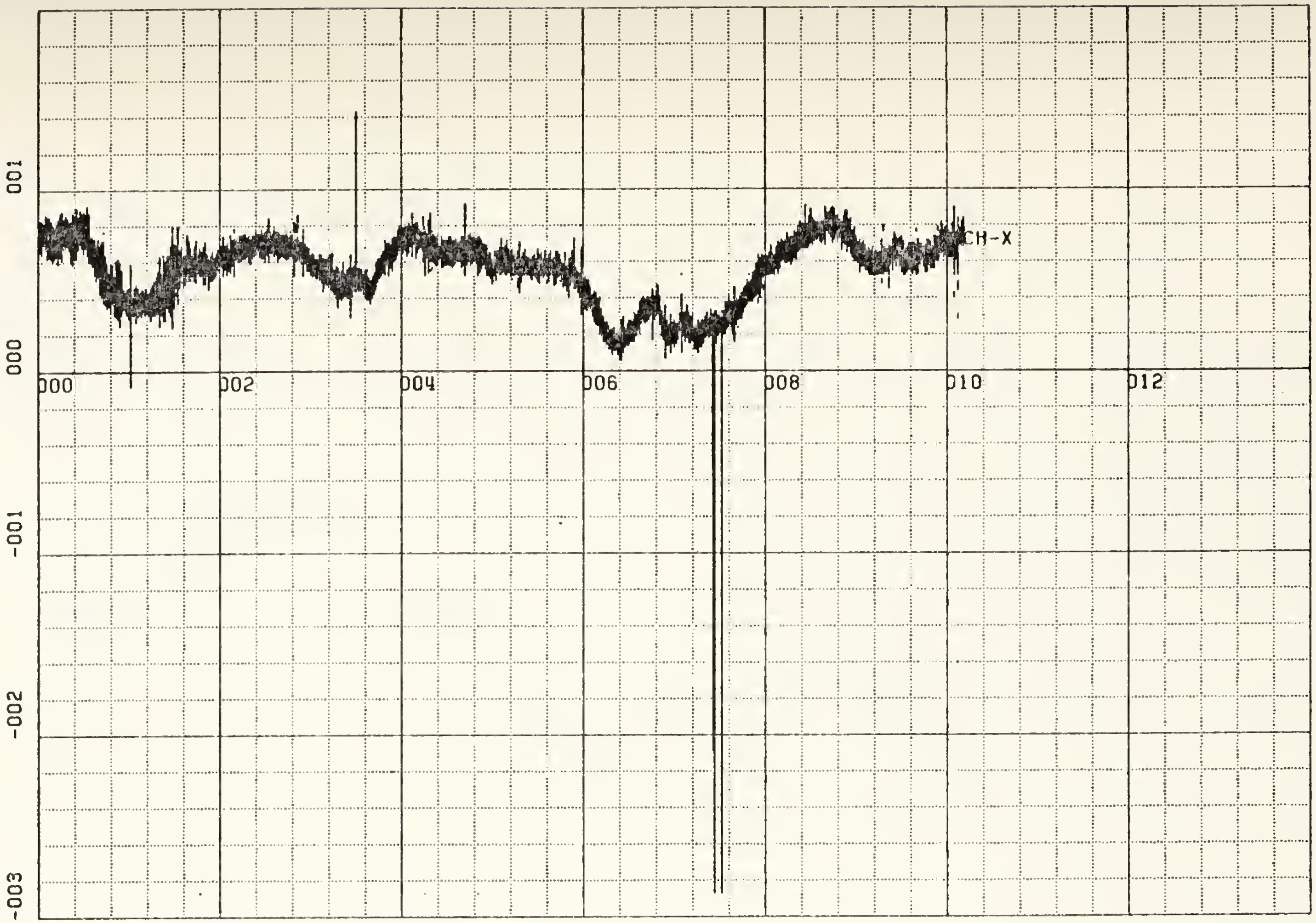

Figure 6.10 X Coil Voltage

Chew's Ridge, 1545 - 1602 Local

Voltage (1 volt/inch) vs Time (200 seconds/inch).

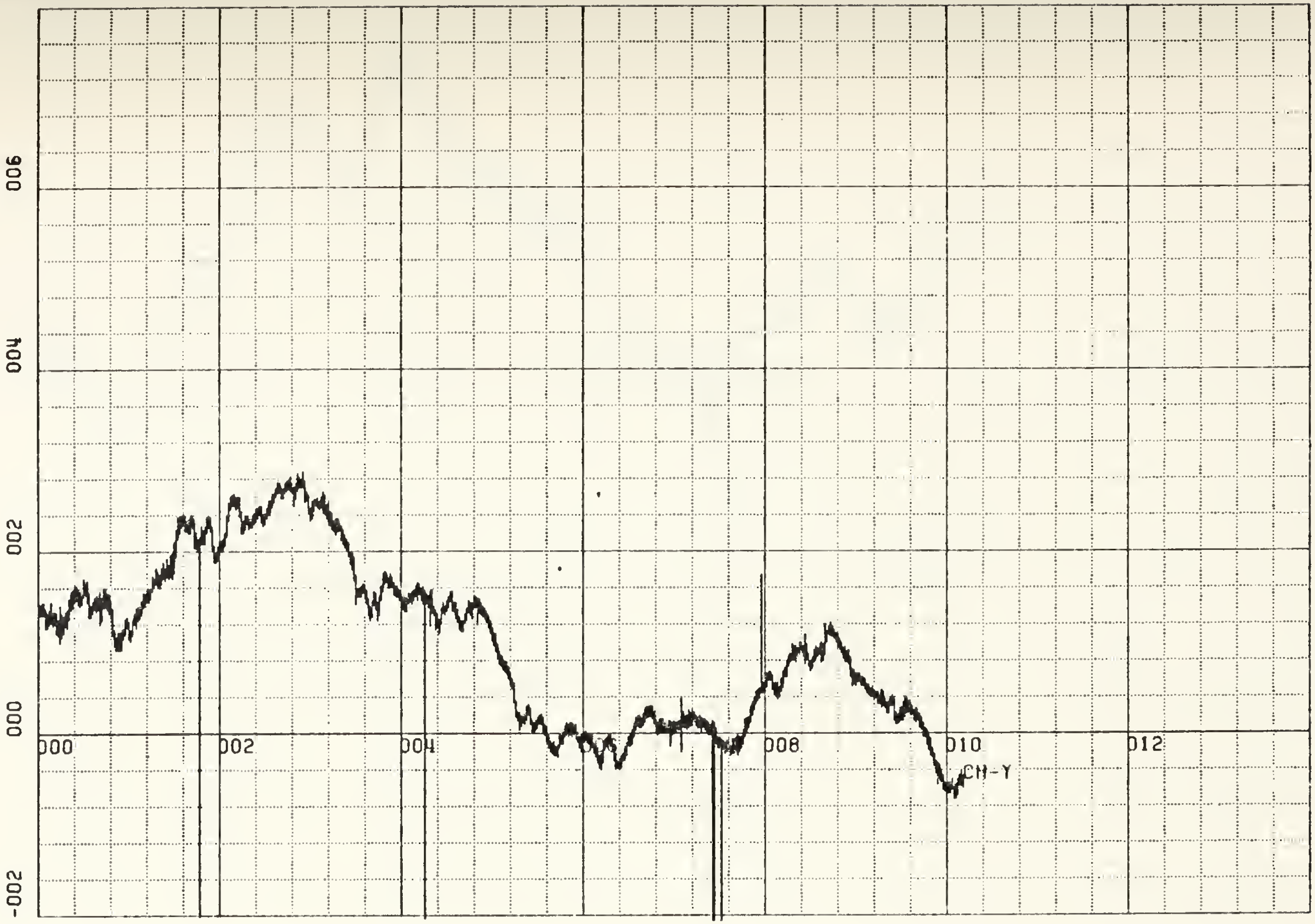

Figure 6.11 Y Coil Voltage

Chew's Ridge, 1545 - 1602 Local

Voltage (2 volts/inch) vs Time (200 seconds/inch).

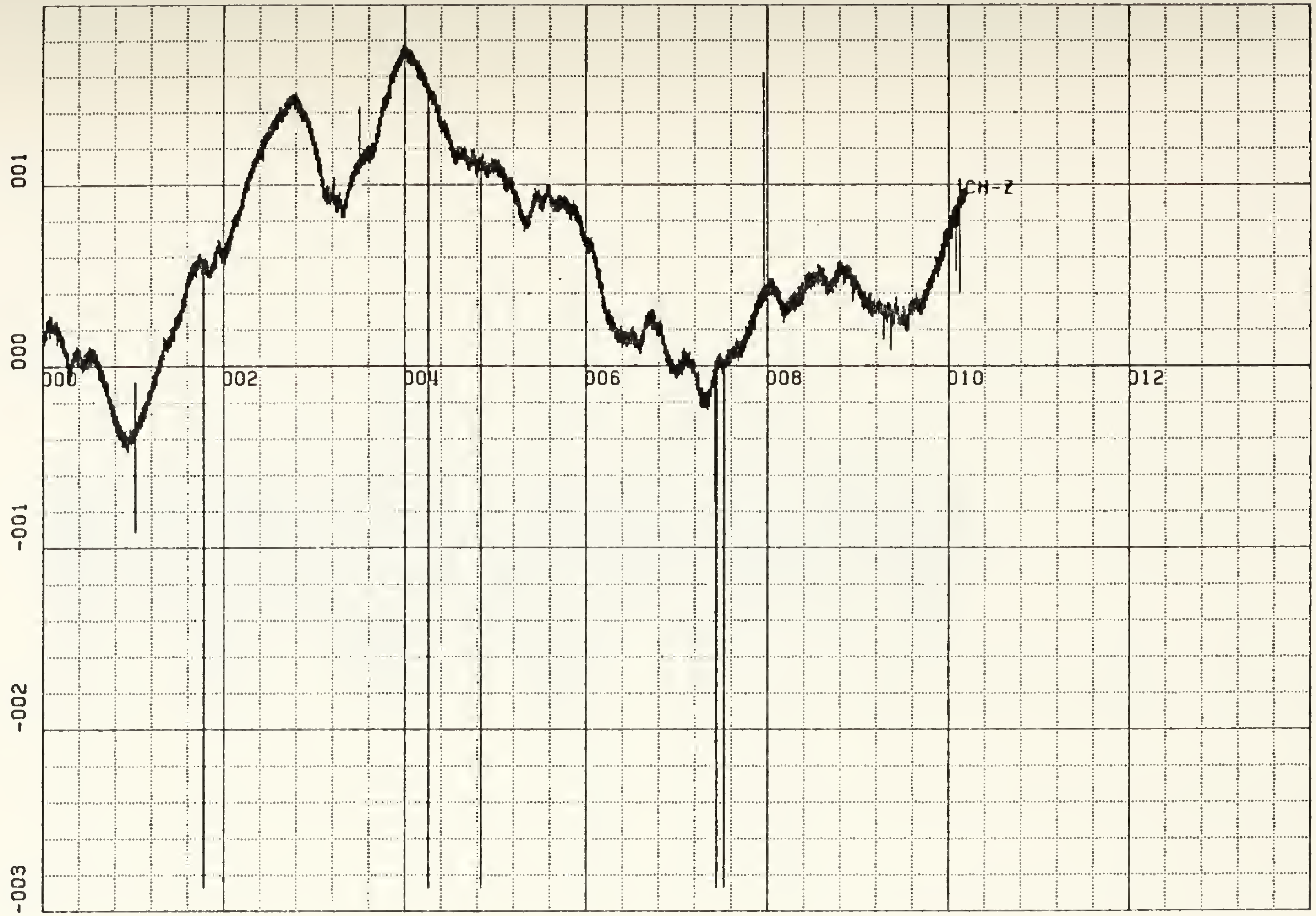

Figure 6.12 Z Coil Voltage

Chew's Ridge, 1545 - 1602 Local

Voltage (1 volt/inch) vs Time (200 seconds/inch).

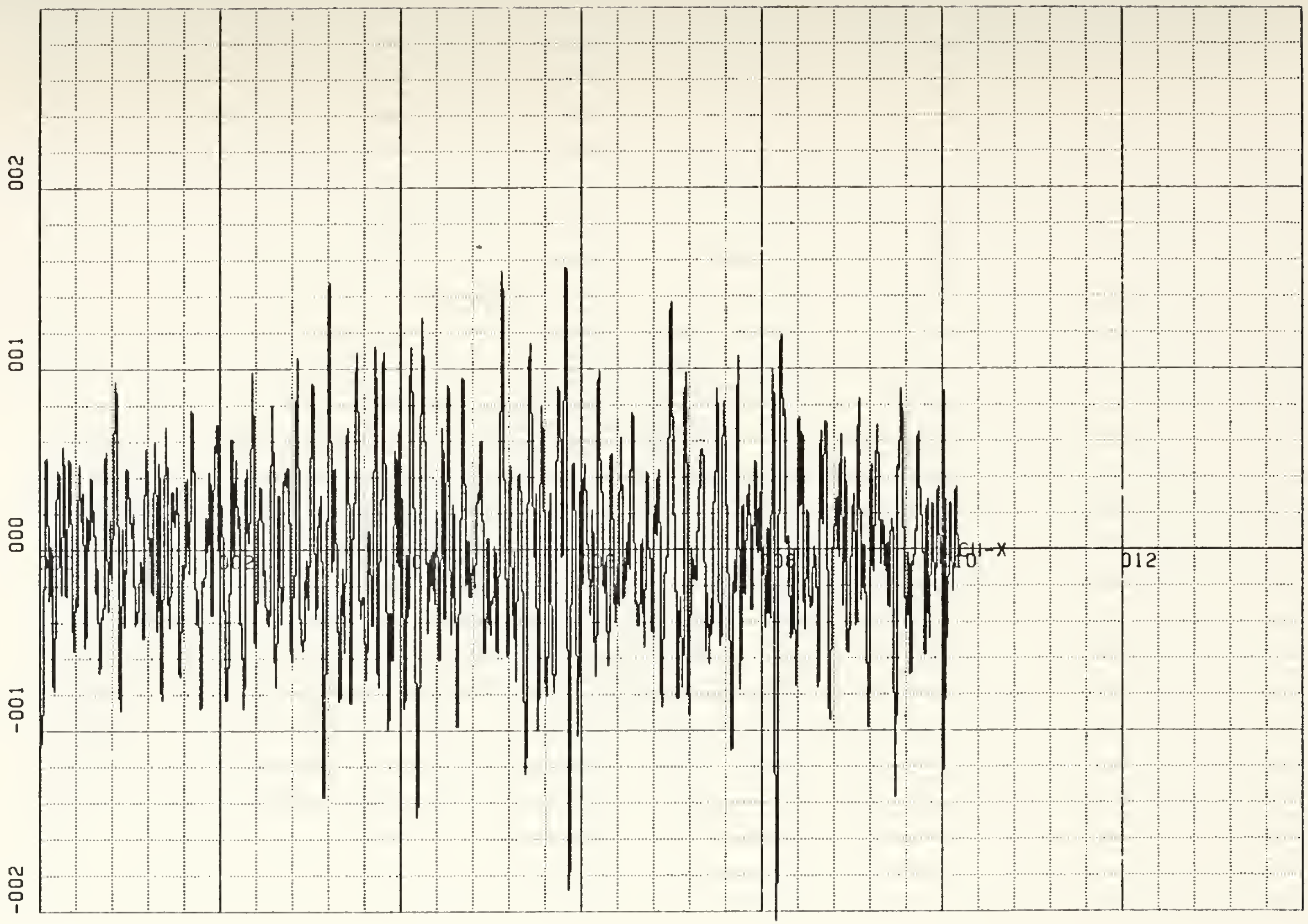

Figure 6.13 X Coil Voltage

La Mesa Village, 1610 - 1627 Local

Voltage (0.02 volts/inch) vs Time (200 seconds/inch).

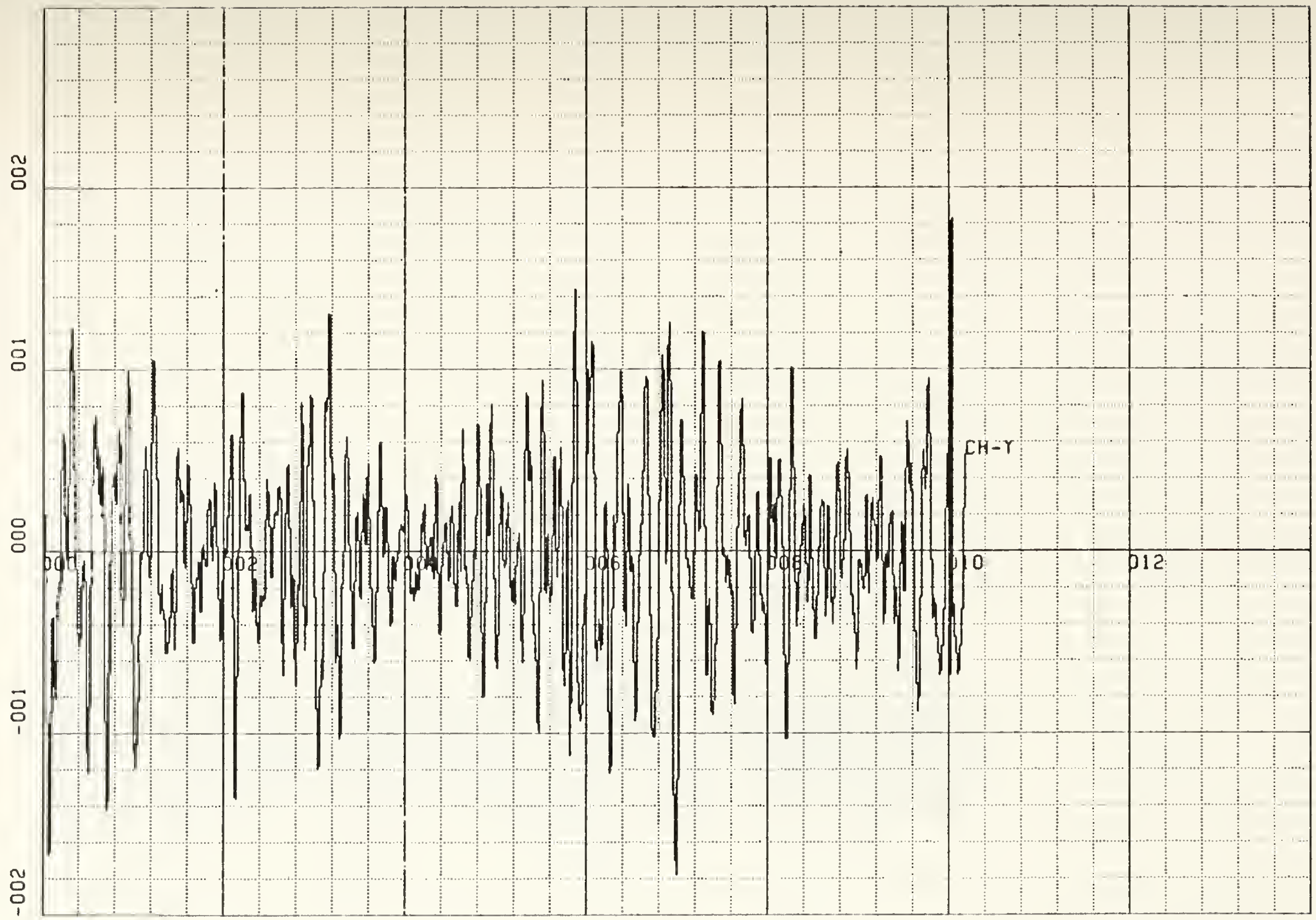

Figure 6.14 Y Coil Voltage

La Mesa Village, 1610 - 1627 Local

Voltage (0.01 volts/inch) vs Time (200 seconds/inch).

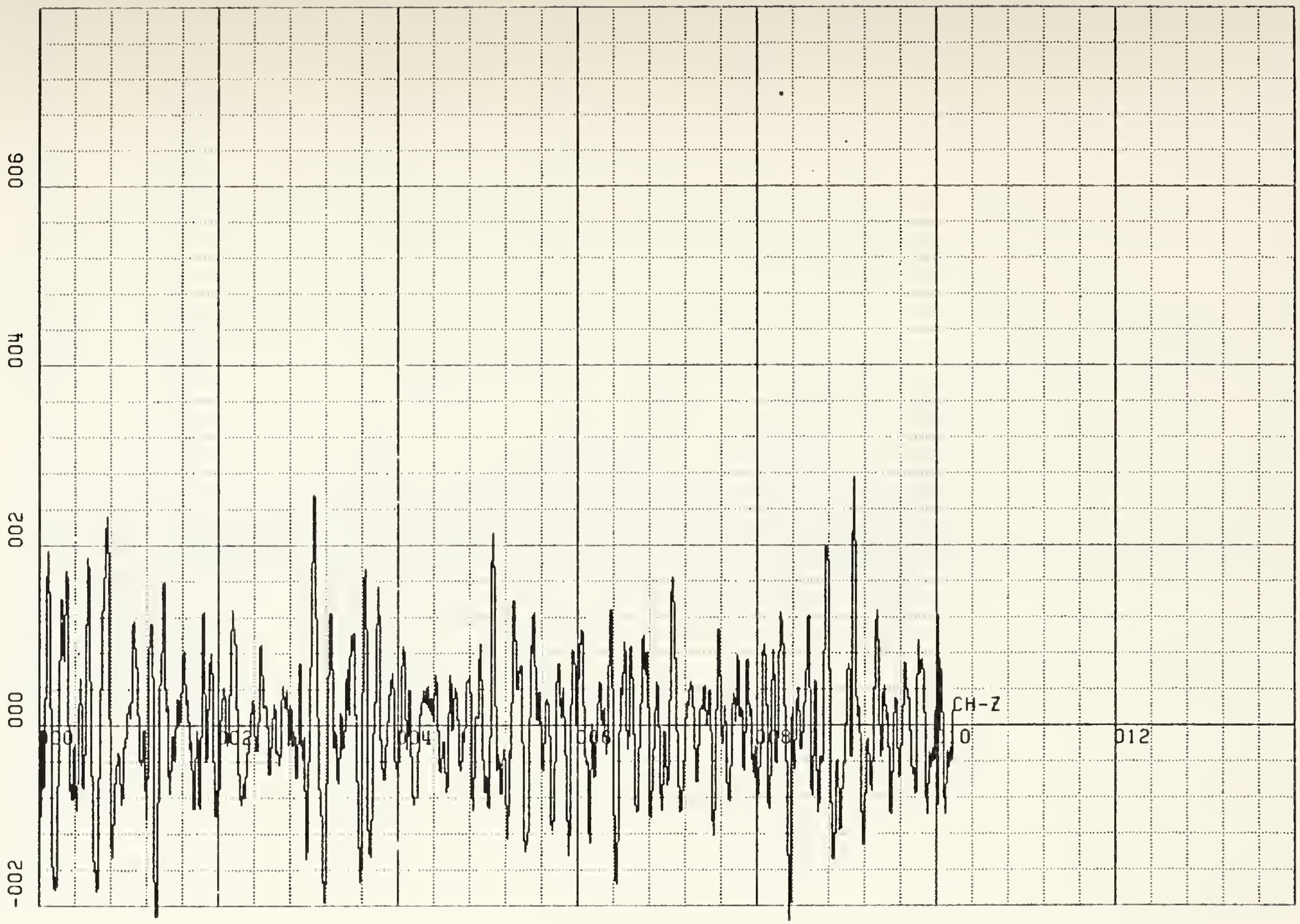

Figure 6.15 Z Coil Voltage

La Mesa Village, 1610 - 1627 Local

Voltage (0.02 volts/inch) vs Time (200 seconds/inch).

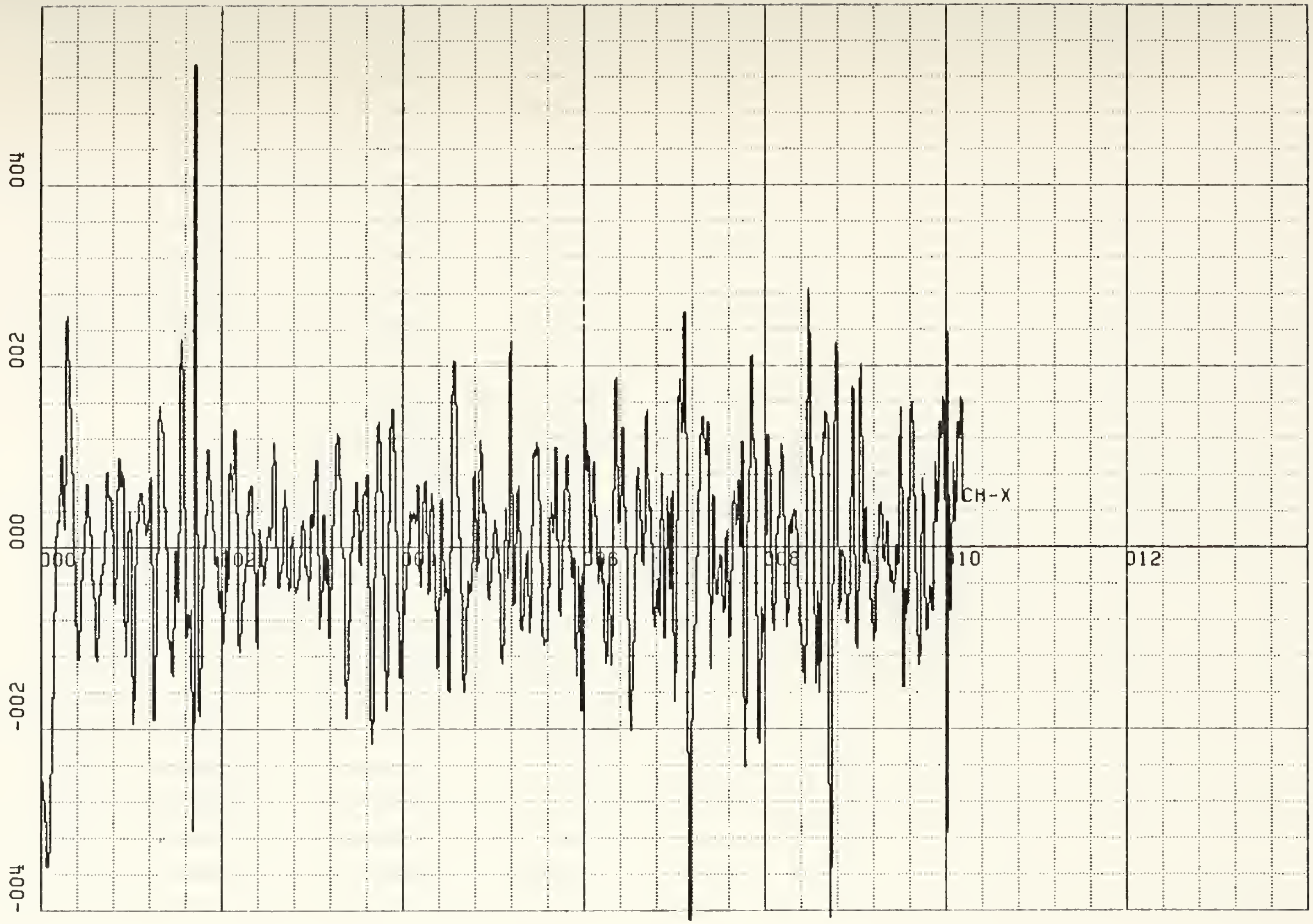

Figure 6.16 X Coil Voltage

Chew's Ridge, 1610 - 1627 Local

Voltage (0.02 volts/inch) vs Time (200 seconds/inch).

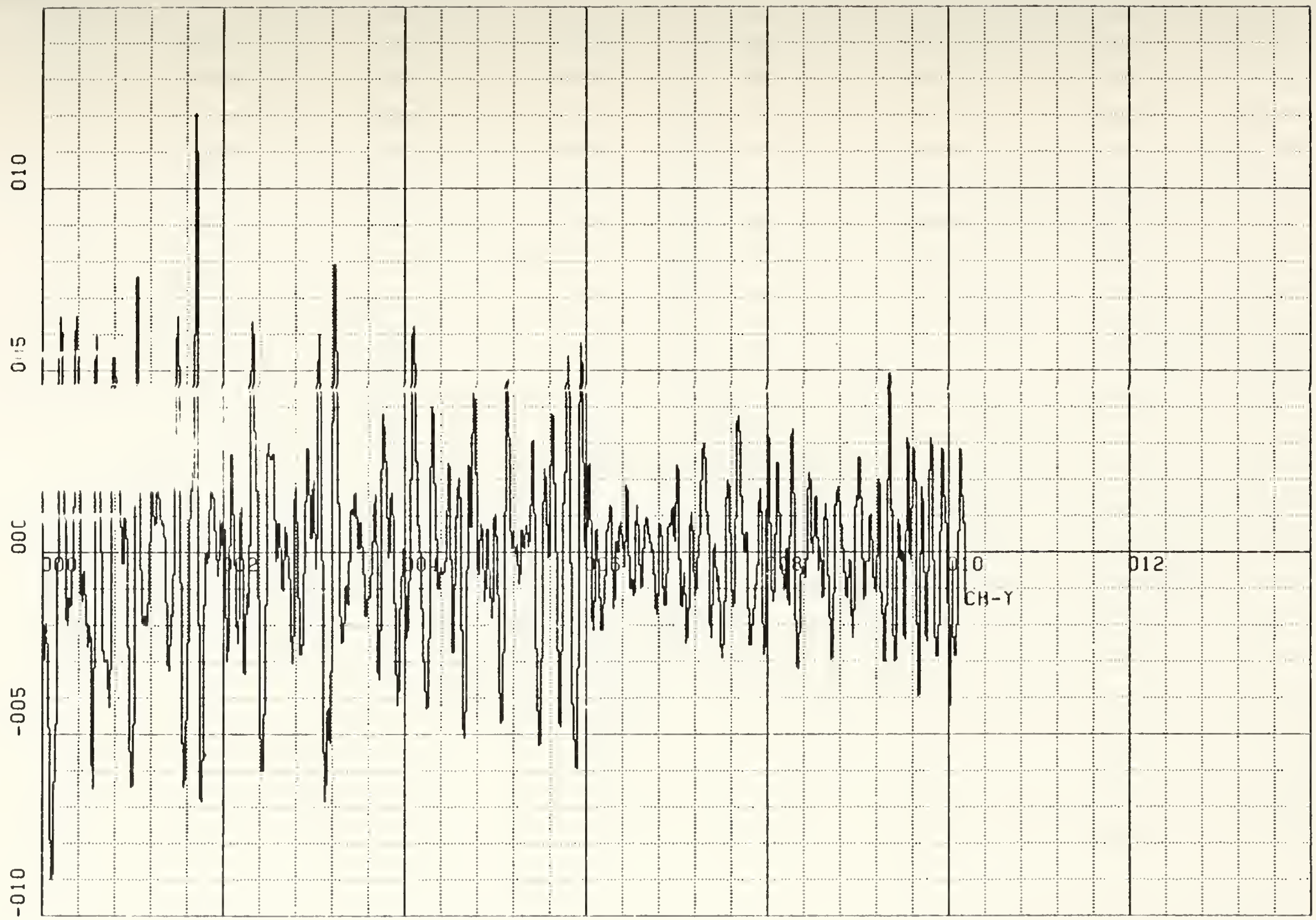

Figure 6.17 Y Coil Voltage

Chew's Ridge, 1610 - 1617 Local

Voltage (0.05 volts/inch) vs Time (200 seconds/inch).

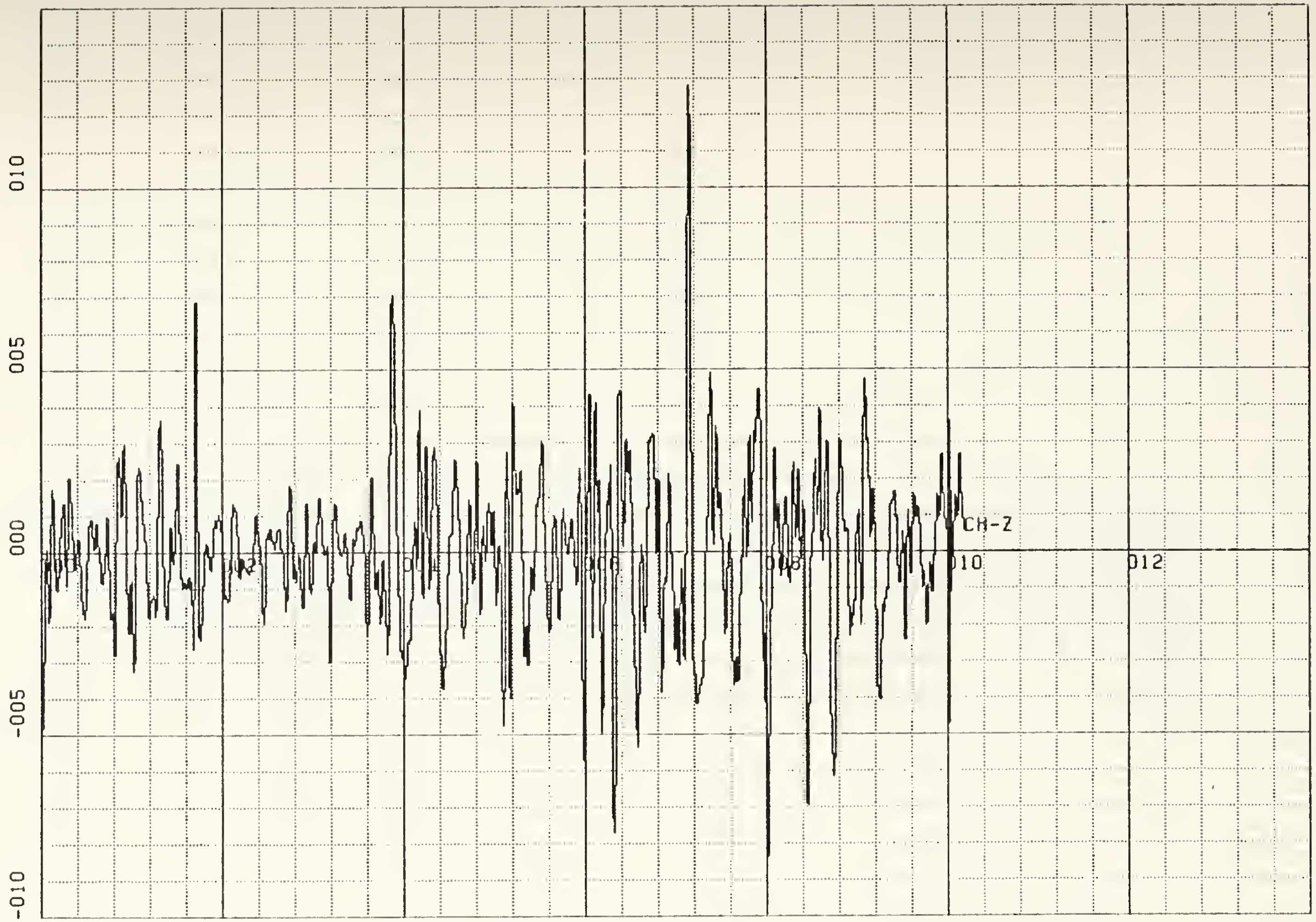

Figure 6.18 Z Coil Voltage

Chew's Ridge, 1610 - 1627 Local

Voltage (0.05 volts/inch) vs Time (200 seconds/inch).

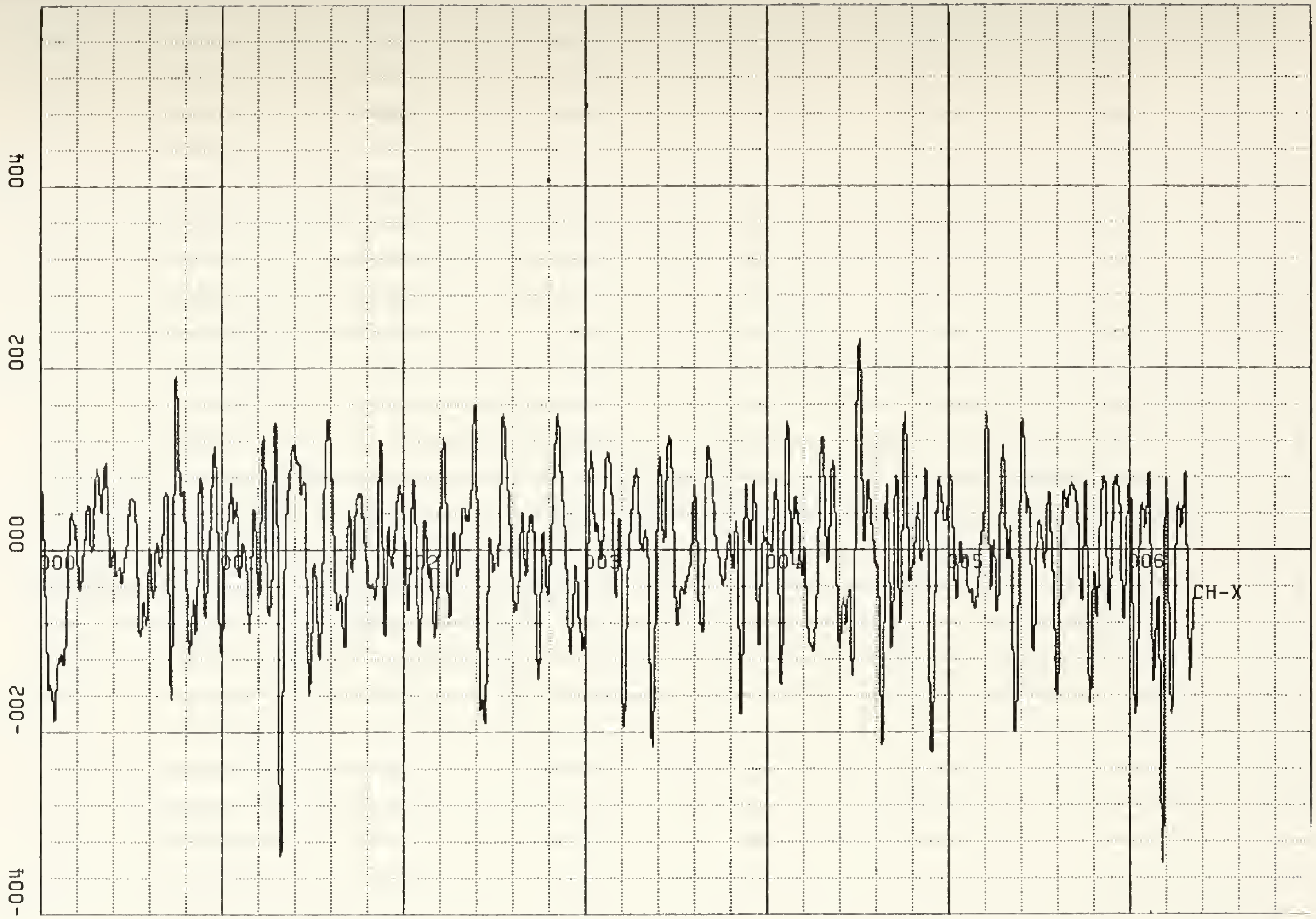

Figure 6.19 X Coil Voltage

La Mesa Village, 1802 - 1812 Local

Voltage (0.02 volts/inch) vs Time (100 seconds/inch).

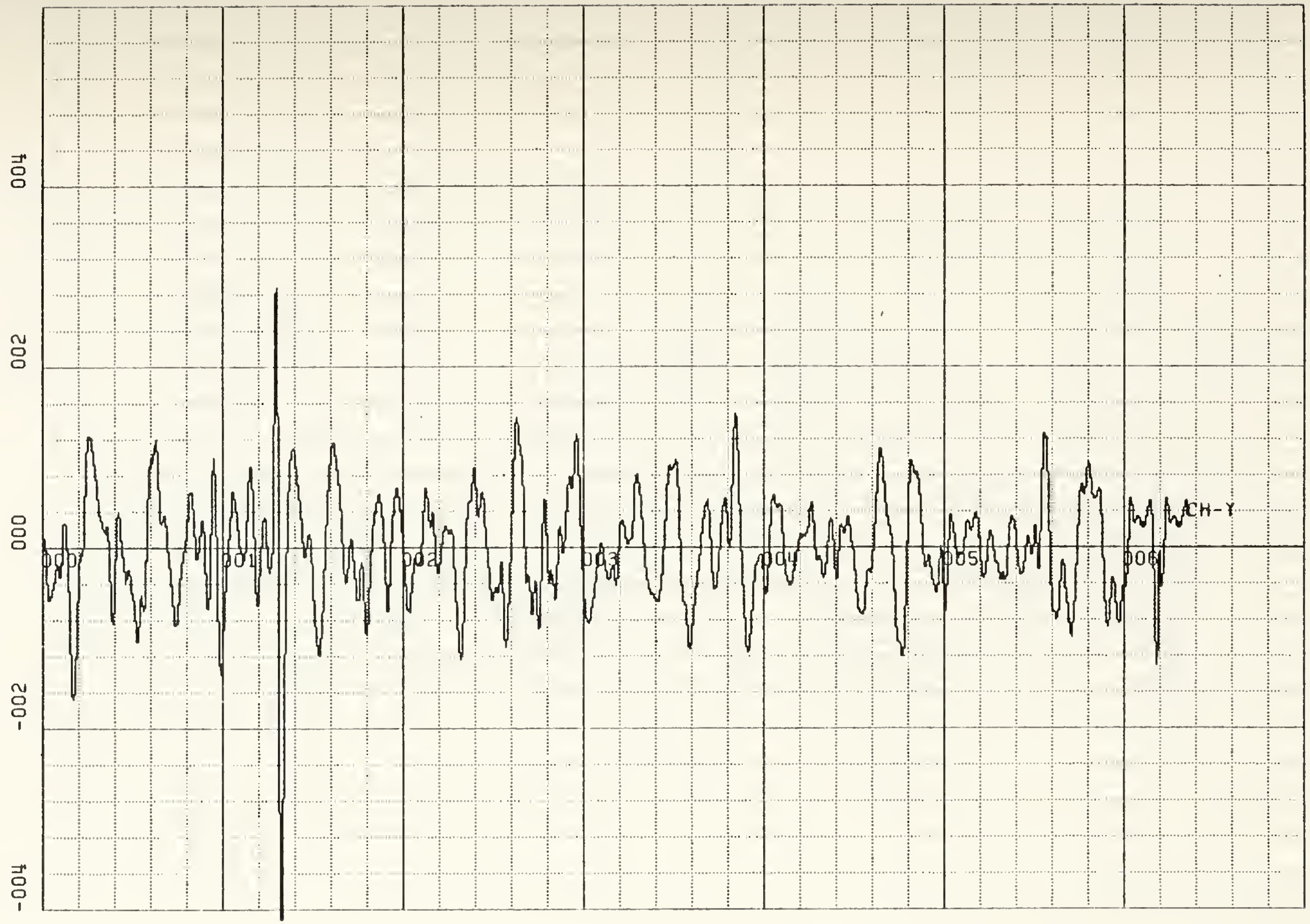

Figure 6.20 Y Coil Voltage

La Mesa Village, 1802 - 1812 Local

Voltage (0.02 volts/inch) vs Time (100 seconds/inch).

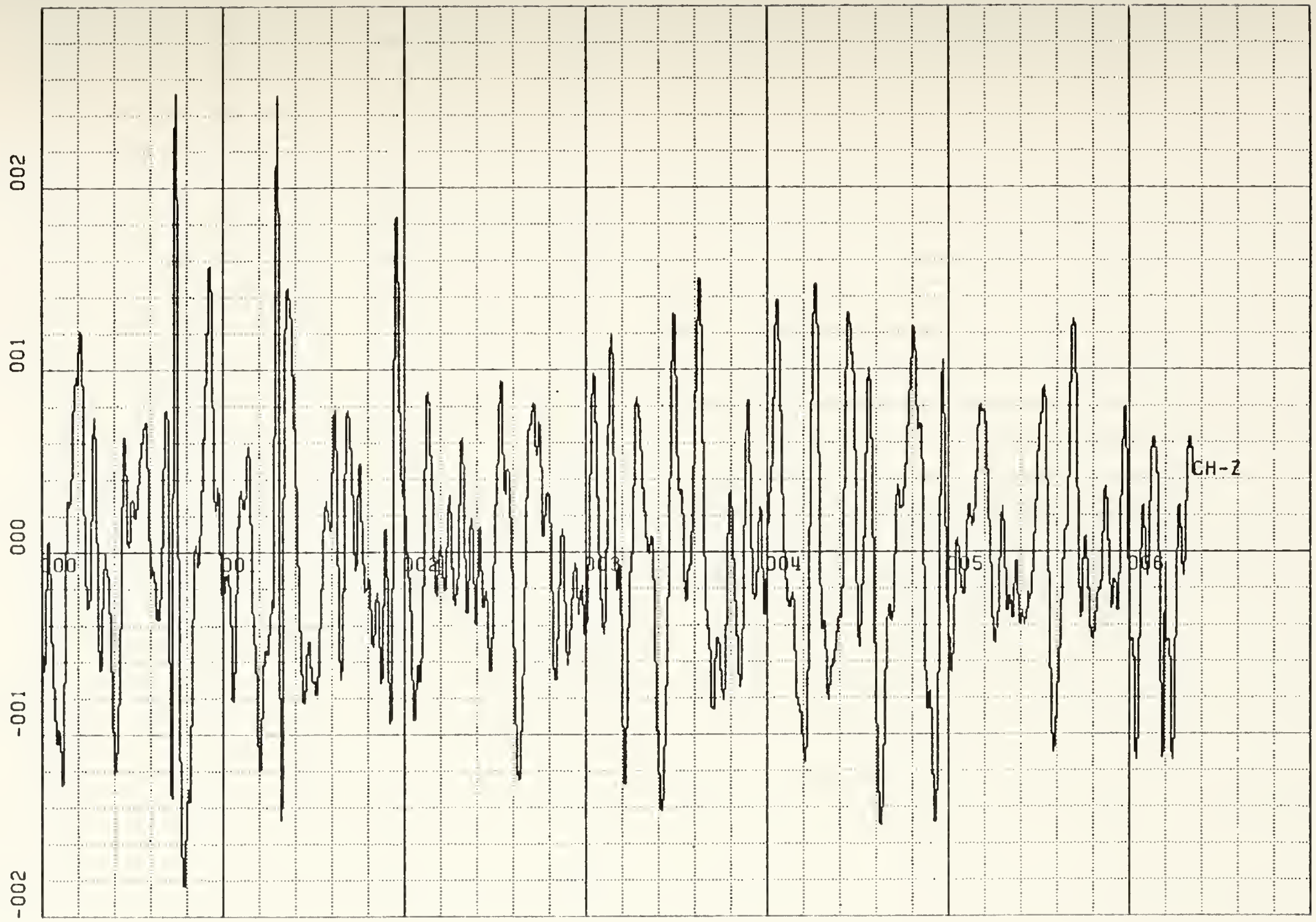

Figure 6.21 Z Coil Voltage

La Mesa Village, 1802 - 1812 Local

Voltage (0.01 volts/inch) vs Time (100 seconds/inch).

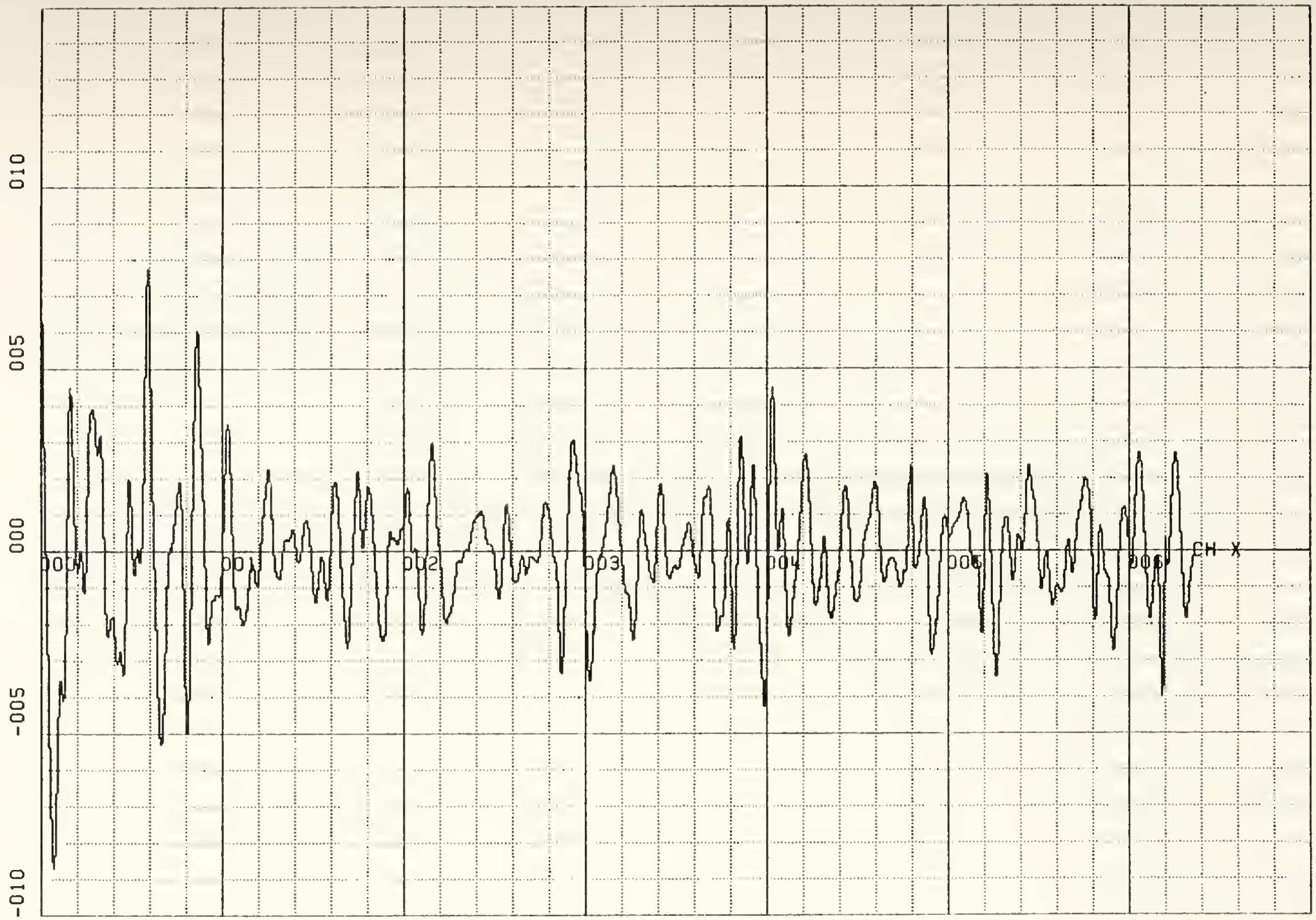

Figure 6.22 X Coil Voltage

Chew's Ridge, 1802 - 1812 Local

Voltage (0.05 volts/inch) vs Time (100 seconds/inch).

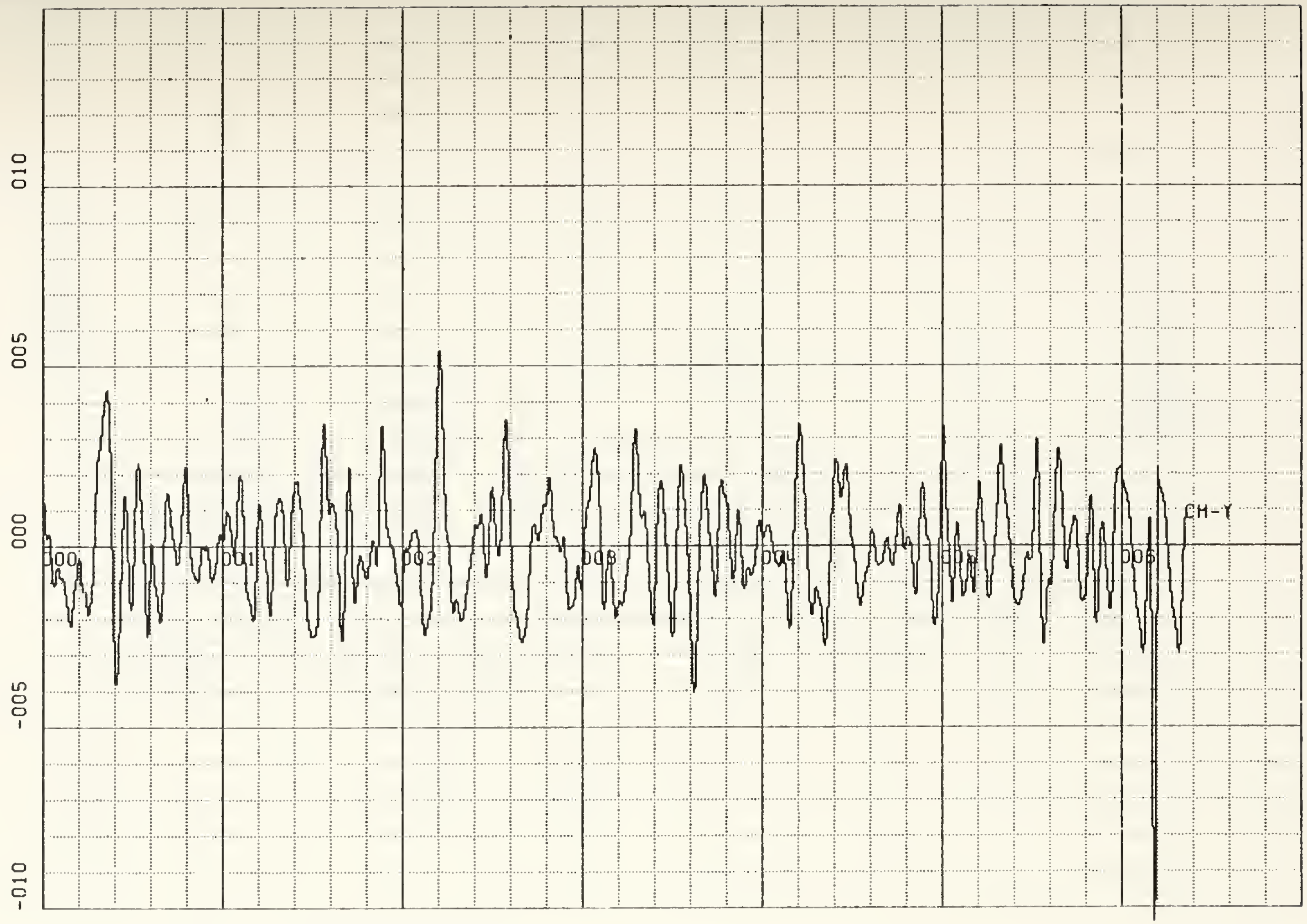

Figure 6.23 Y Coil Voltage

Chew's Ridge, 1802 - 1812 Local

Voltage (0.05 volts/inch) vs Time (100 seconds/inch).

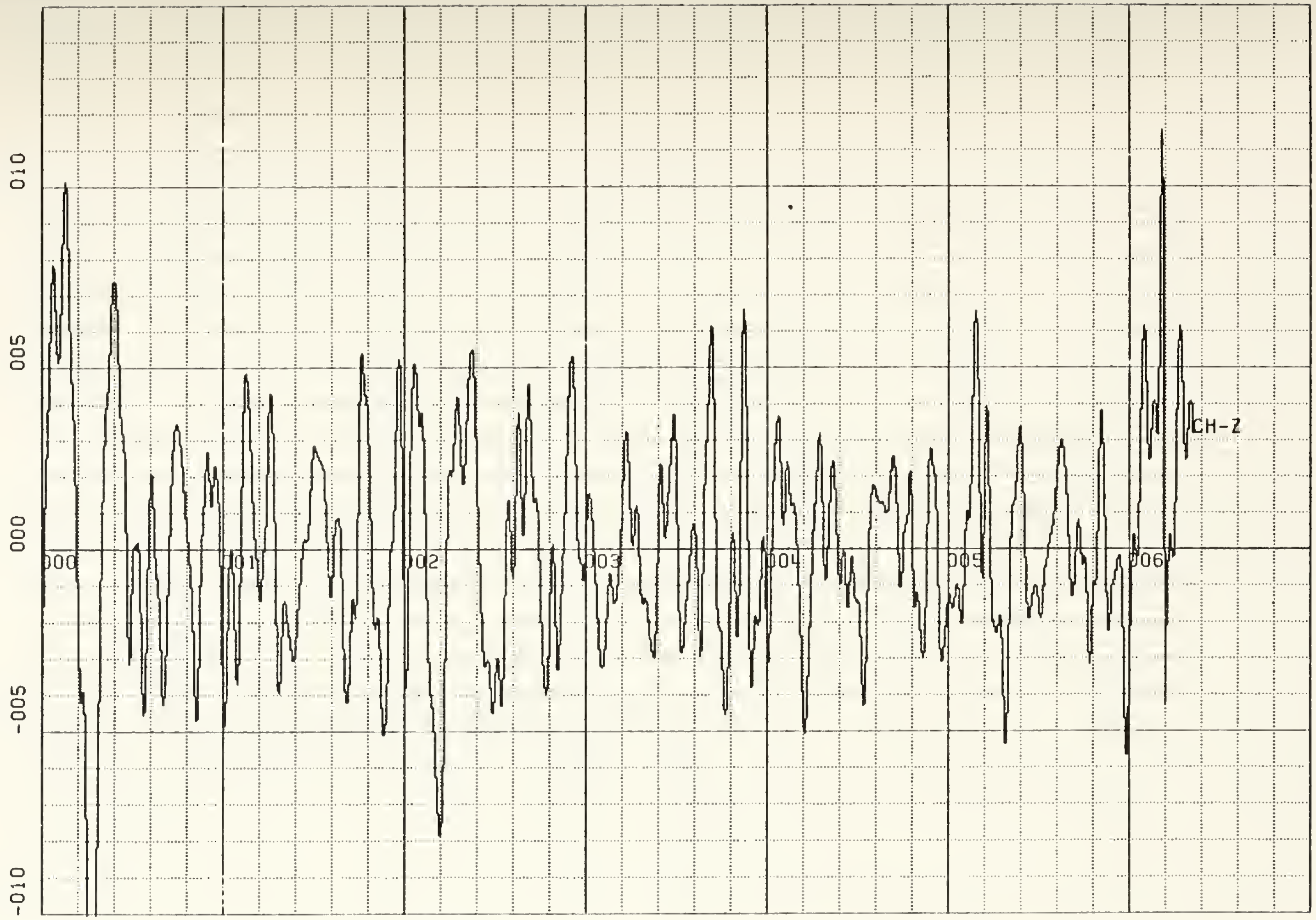

Figure 6.24 Z Coil Voltage

Chew's Ridge, 1802 - 1812 Local

Voltage (0.05 volts/inch) vs Time (100 seconds/inch).

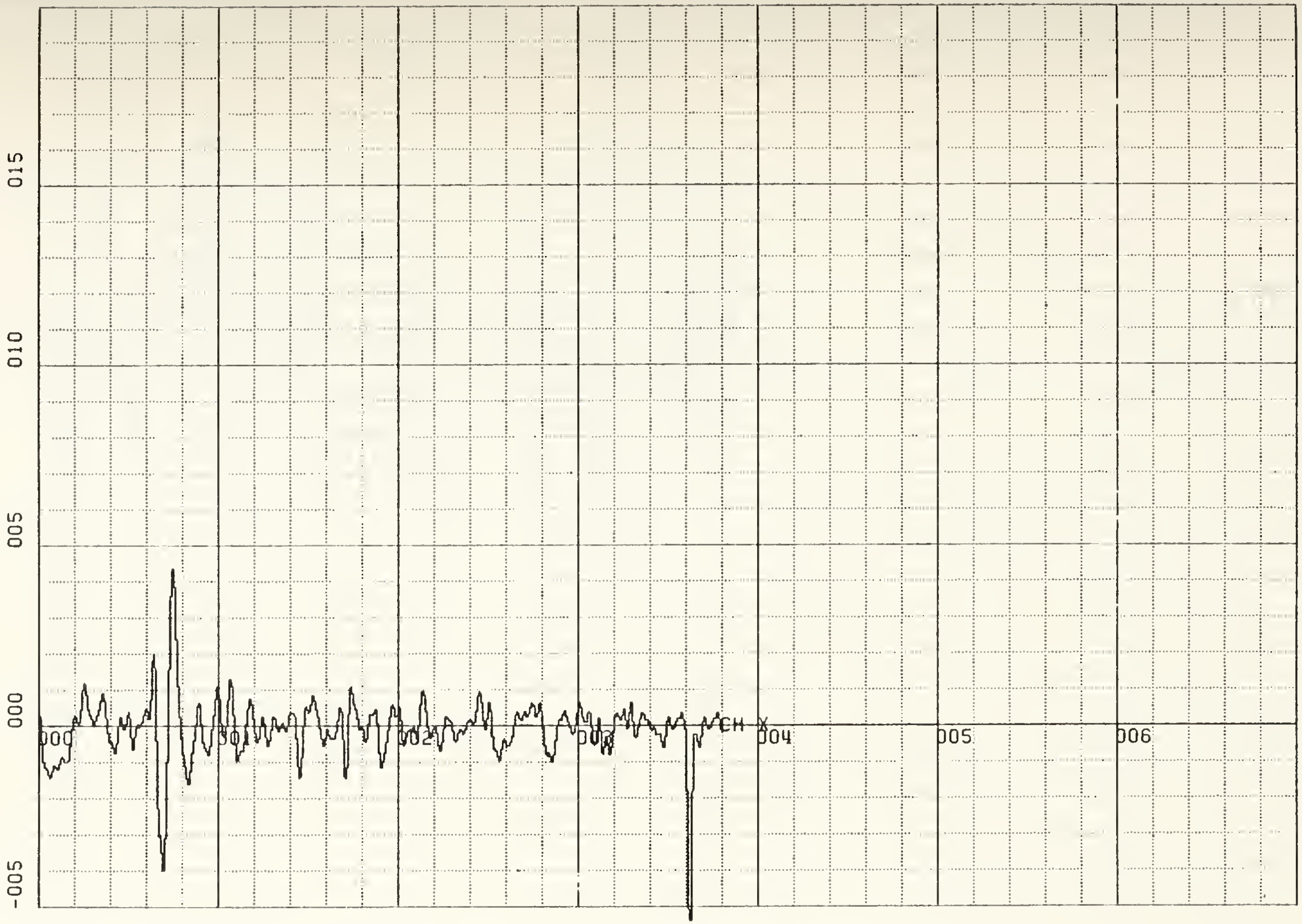

Figure 6.25 X Coil Voltage

La Mesa Village, 1834 - 1840 Local

Voltage (0.05 volts/inch) vs Time (100 seconds/inch).

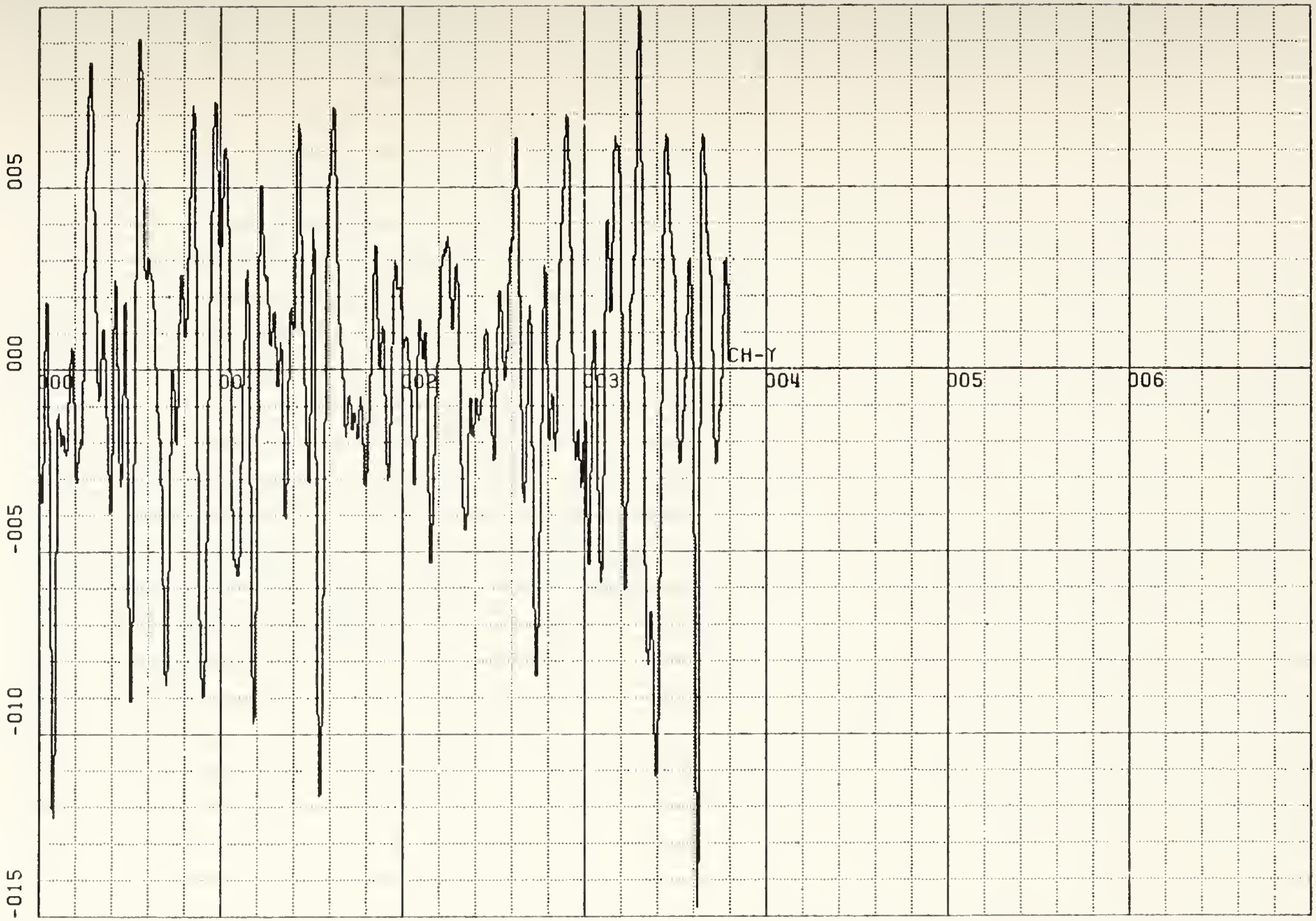

Figure 6.26 Y Coil Voltage

La Mesa Village, 1834 - 1840 Local

Voltage (0.005 volts/inch) vs Time (100 seconds/inch).

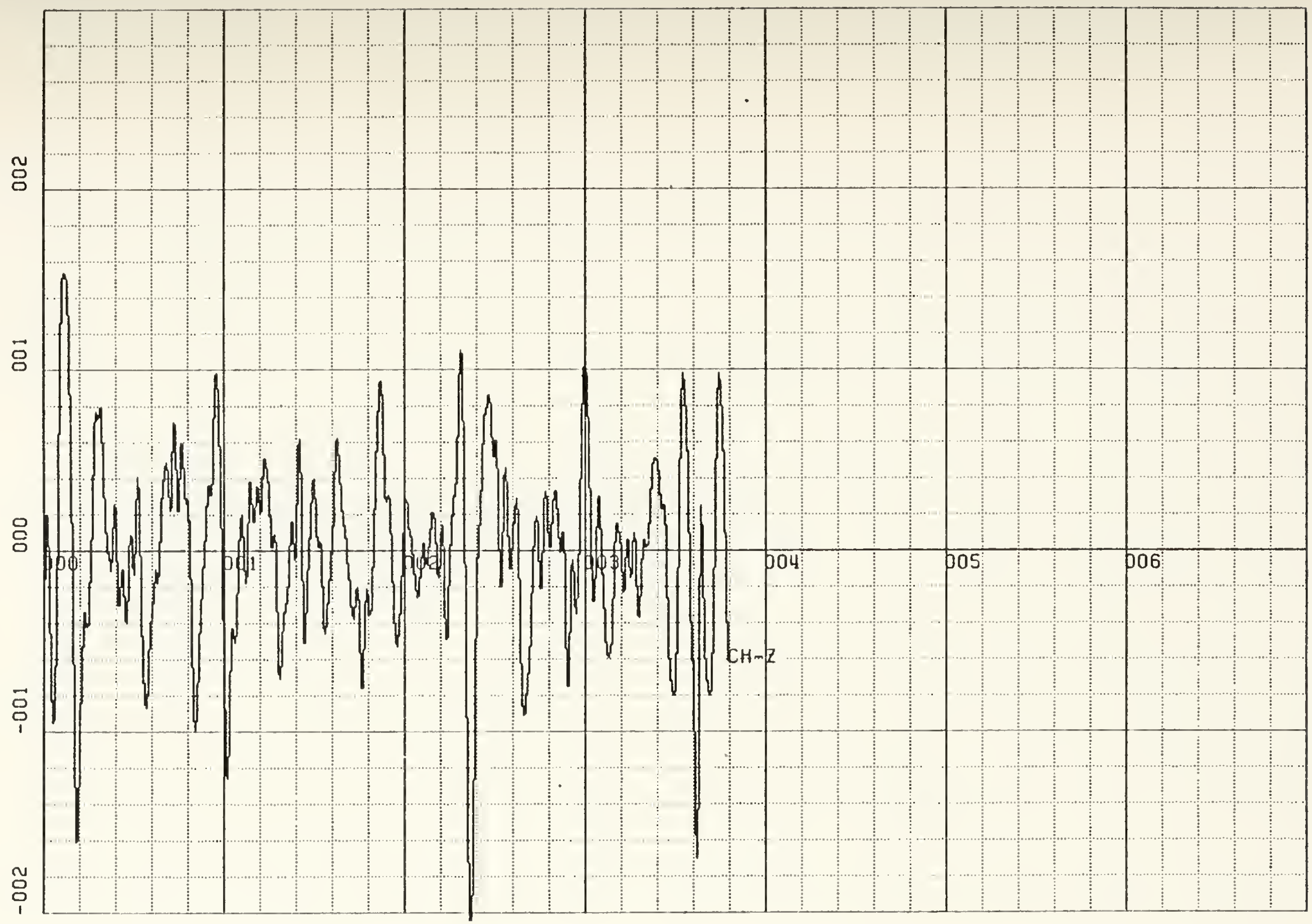

Figure 6.27 Z Coil Voltage

La Mesa Village, 1834 - 1840 Local

Voltage (0.01 volts/inch) vs Time (100 seconds/inch).

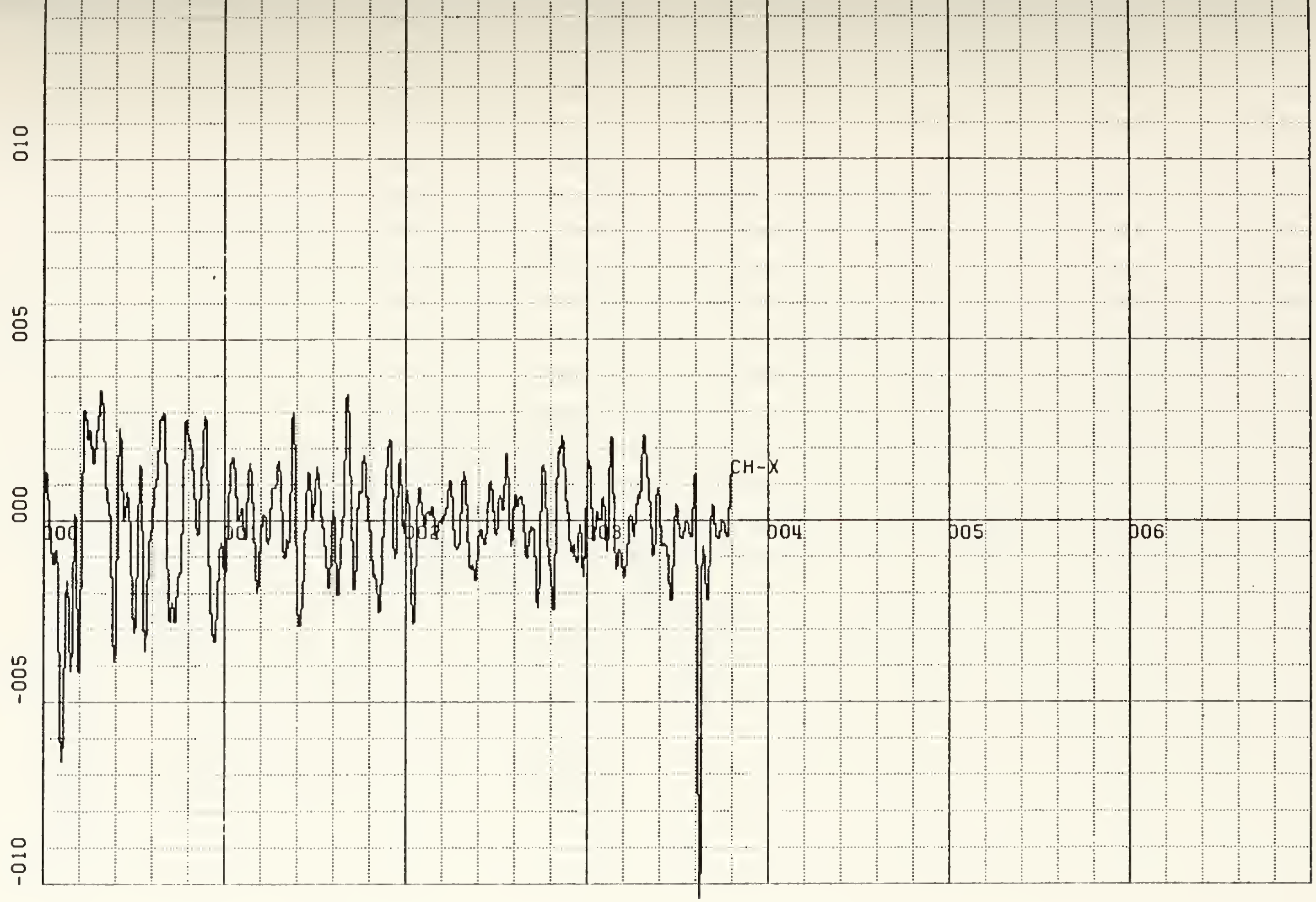

Figure 6.28 X Coil Voltage

Chew's Ridge, 1834 - 1840 Local

Voltage (0.05 volts/inch) vs Time (100 seconds/inch).

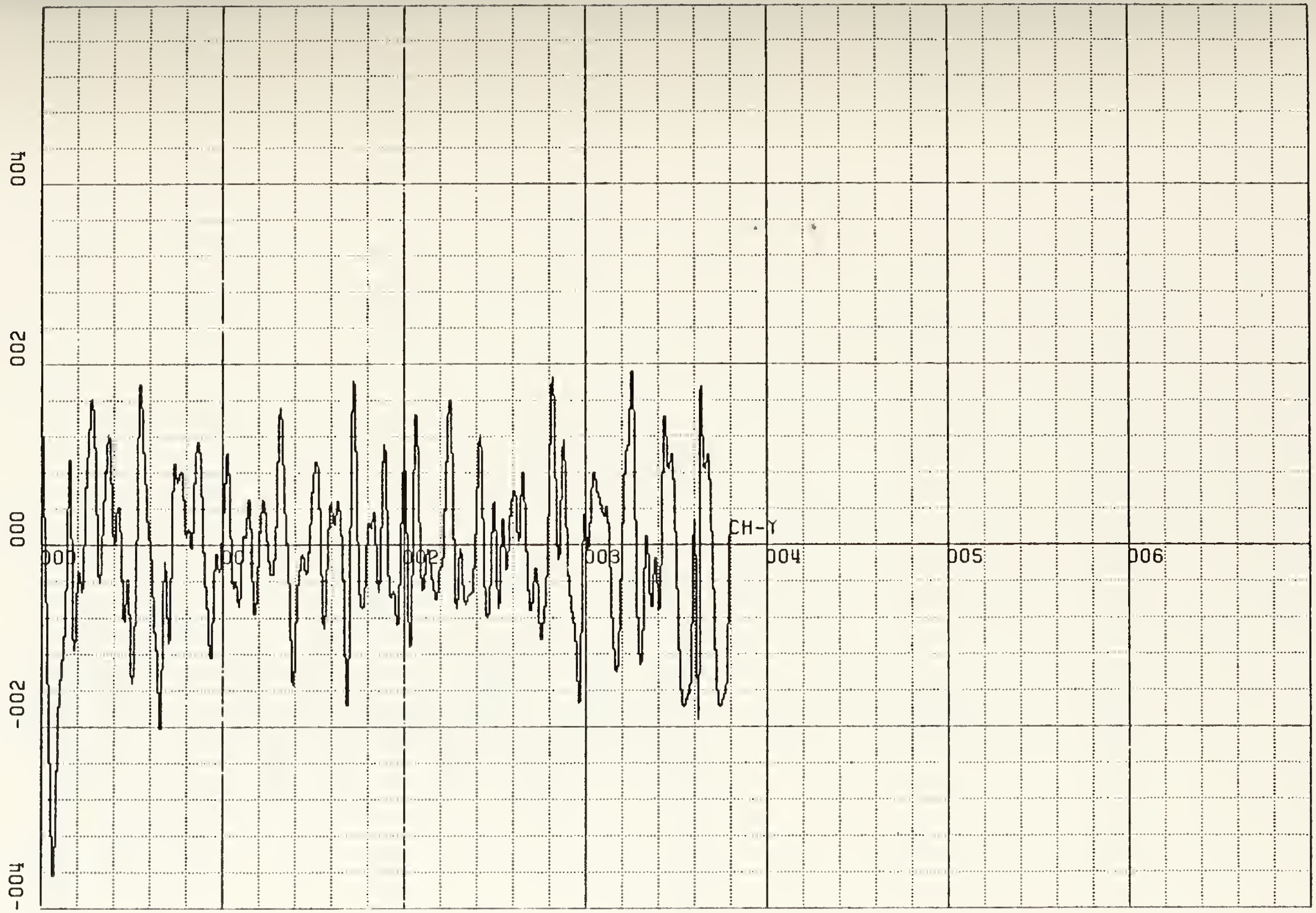

Figure 6.29 Y Coil Voltage

Chew's Ridge, 1834 - 1840 Local

Voltage (0.02 volts/inch) vs Time (100 seconds/inch).

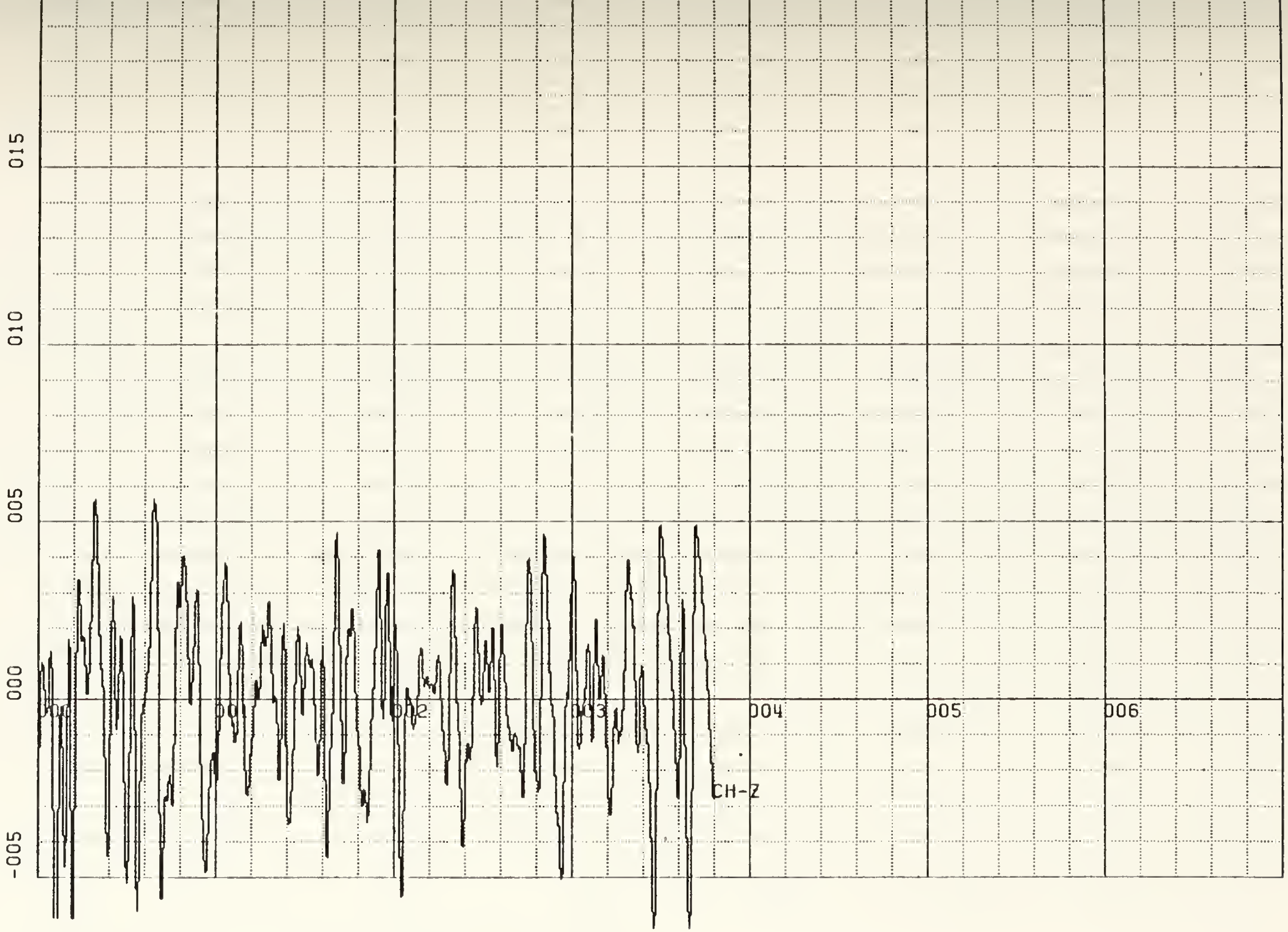

Figure 6.30 Z Coil Voltage

Chew's Ridge, 1834 - 1840 Local

Voltage (0.05 volts/inch) vs Time (100 seconds/inch).

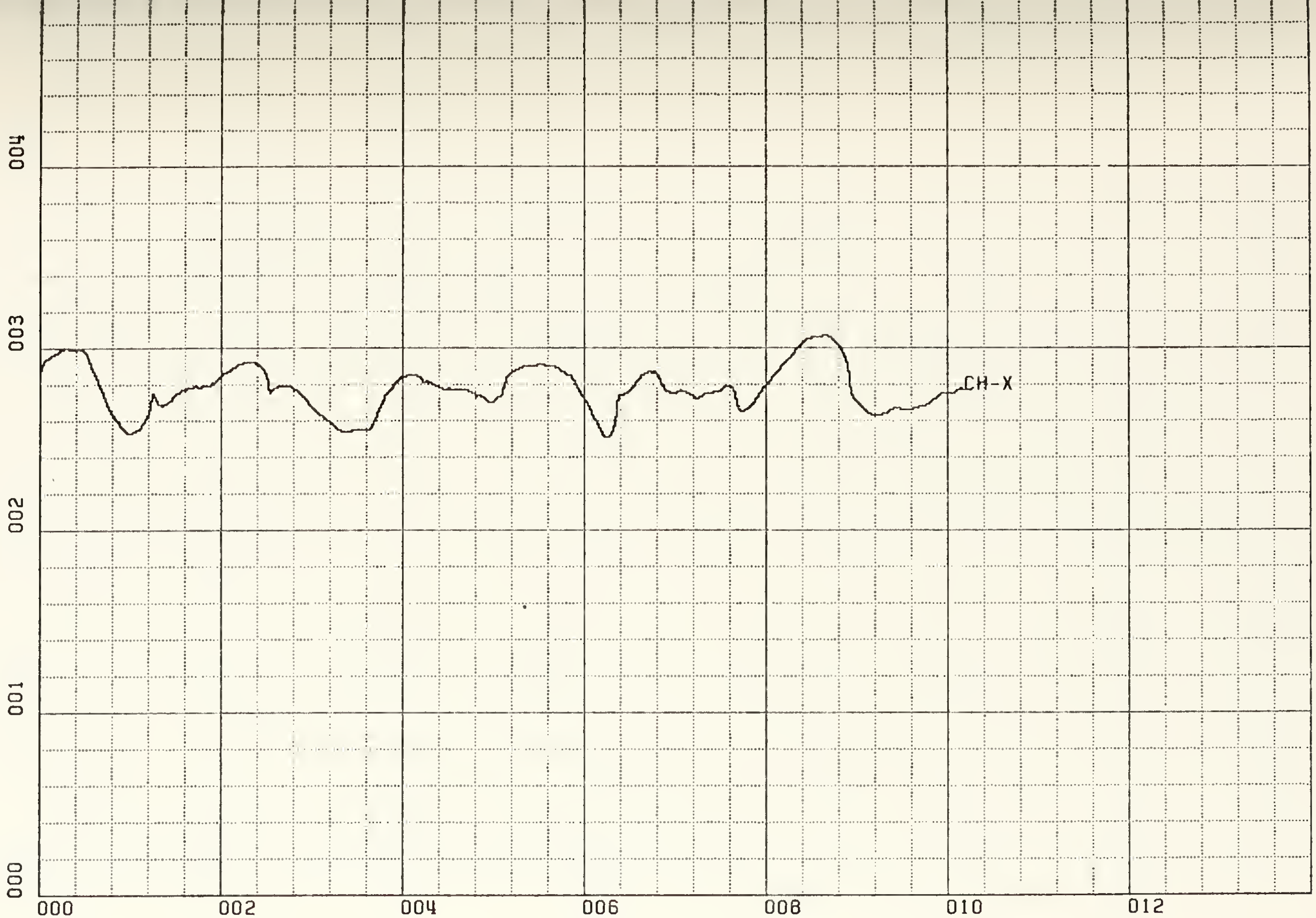

Figure 6.31 X Coil Magnetic Field

Chew's Ridge, 1545 - 1602 Local

Field (10 nanoteslas/inch) vs Time (200 seconds/inch).

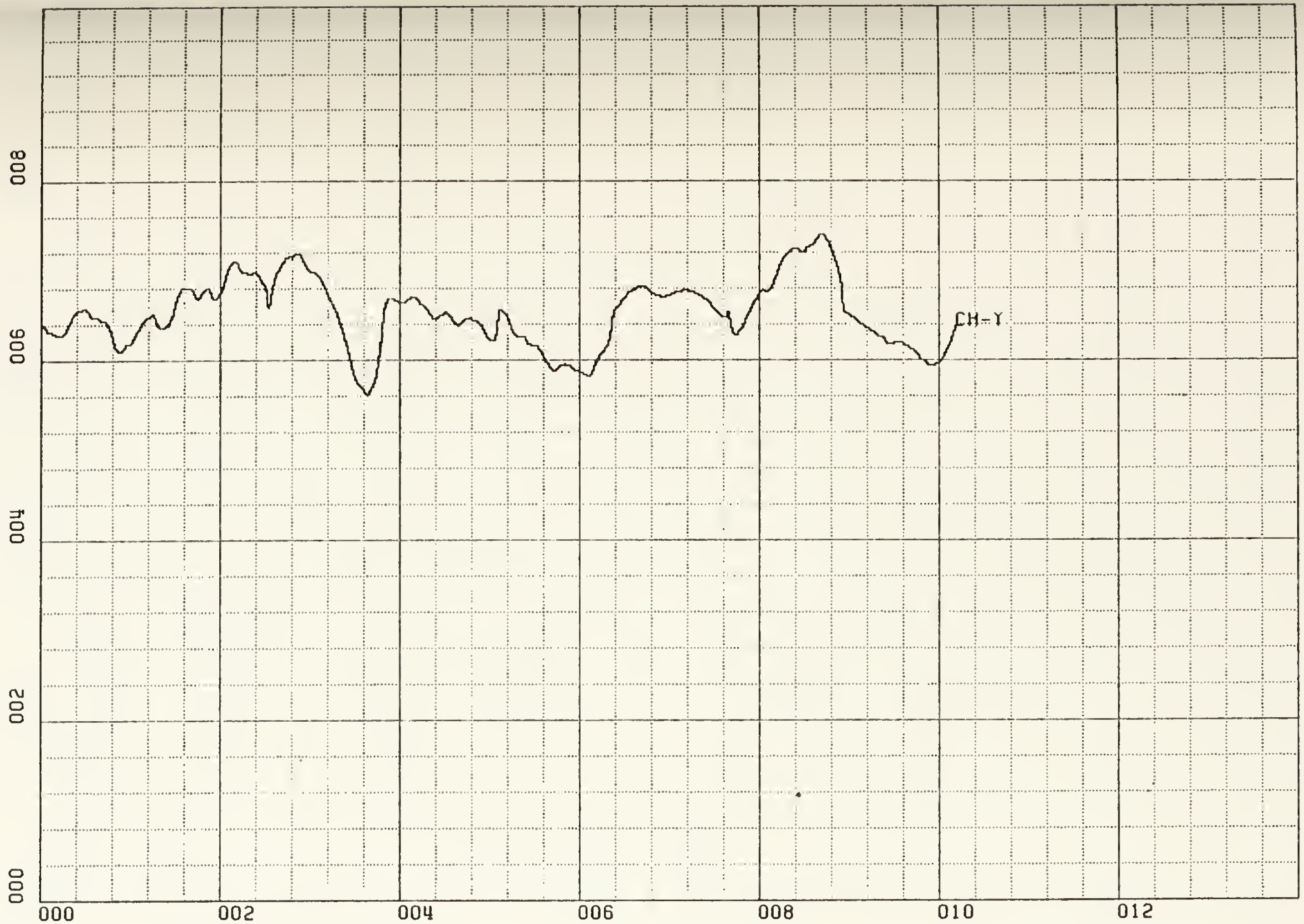

Figure 6.32 Y Coil Magnetic Field

Chew's Ridge, 1545 - 1602 Local

Field (20 nanoteslas/inch) vs Time (200 seconds/inch).

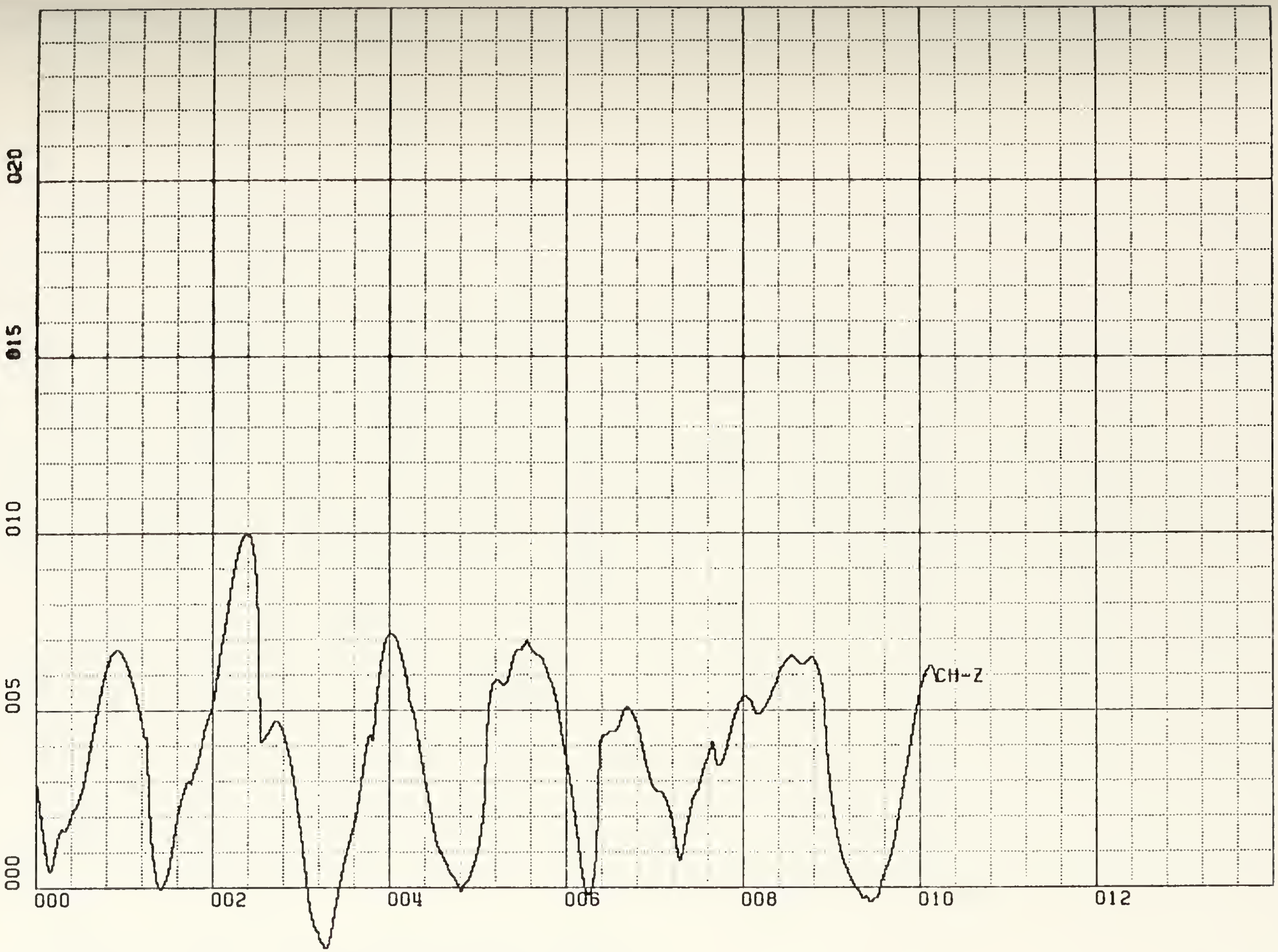

Figure 6.33 X Coil Magnetic Field

Chew's Ridge, 1545 - 1602 Local

Field (5 nanoteslas/inch) vs Time (200 seconds/inch).

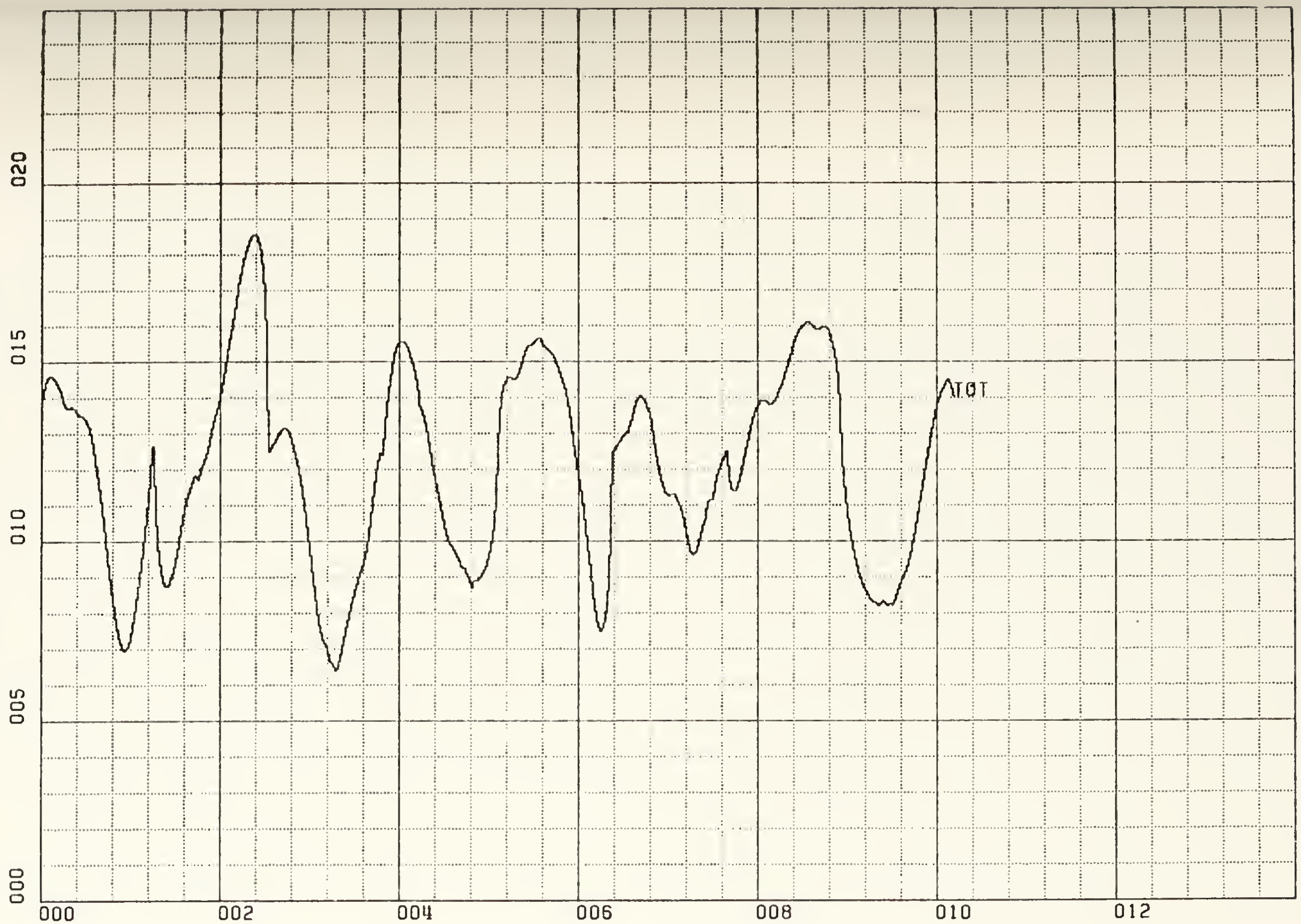

Figure 6.34 Total Magnetic Field

Chew's Ridge, 1545 - 1602 Local

Field (5 nanoteslas/inch) vs Time (200 seconds/inch).

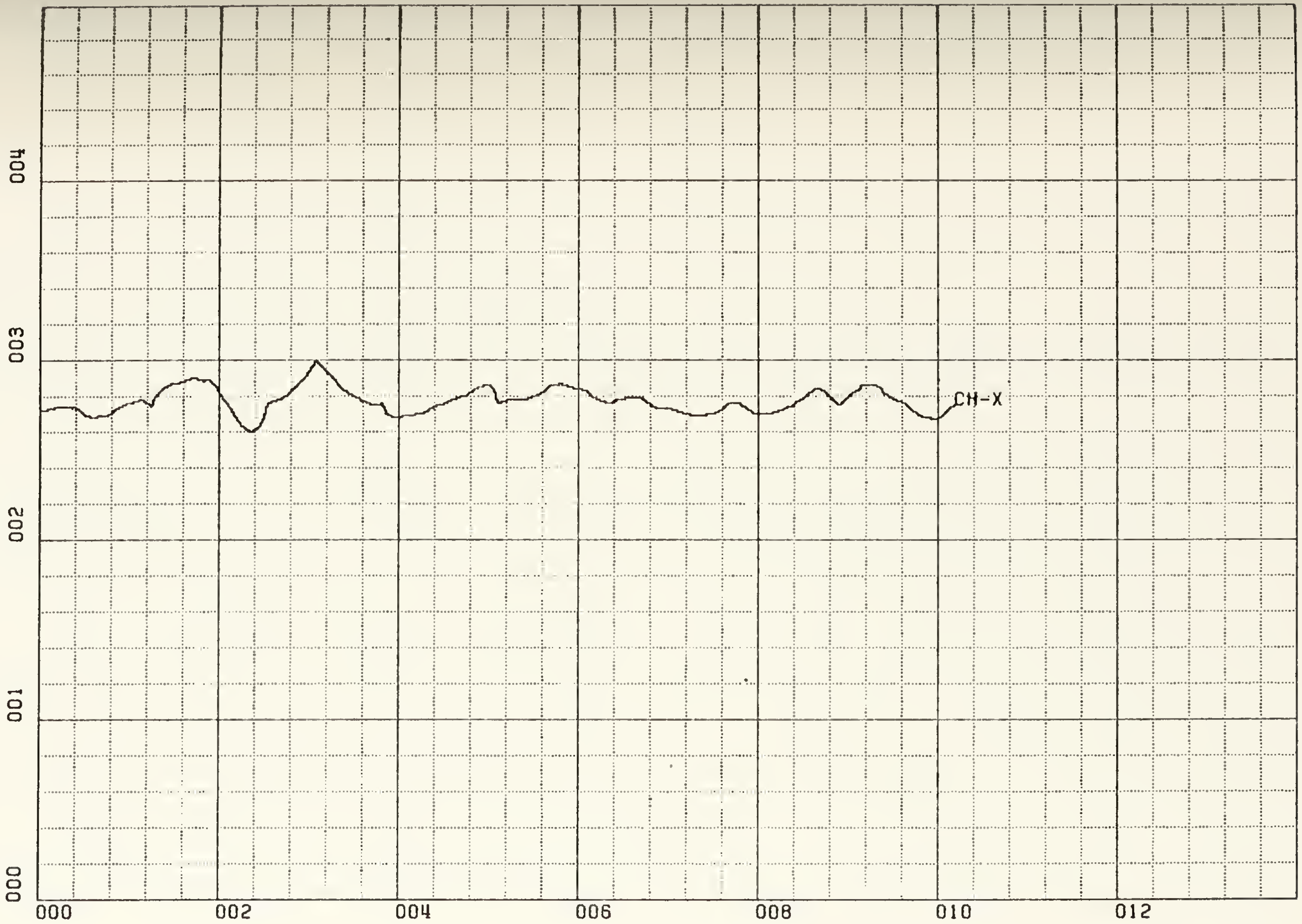

Figure 6.35 X Coil Magnetic Field

Chew's Ridge, 1310 - 1317 Local

Field (10 nanoteslas/inch) vs Time (200 seconds/inch).

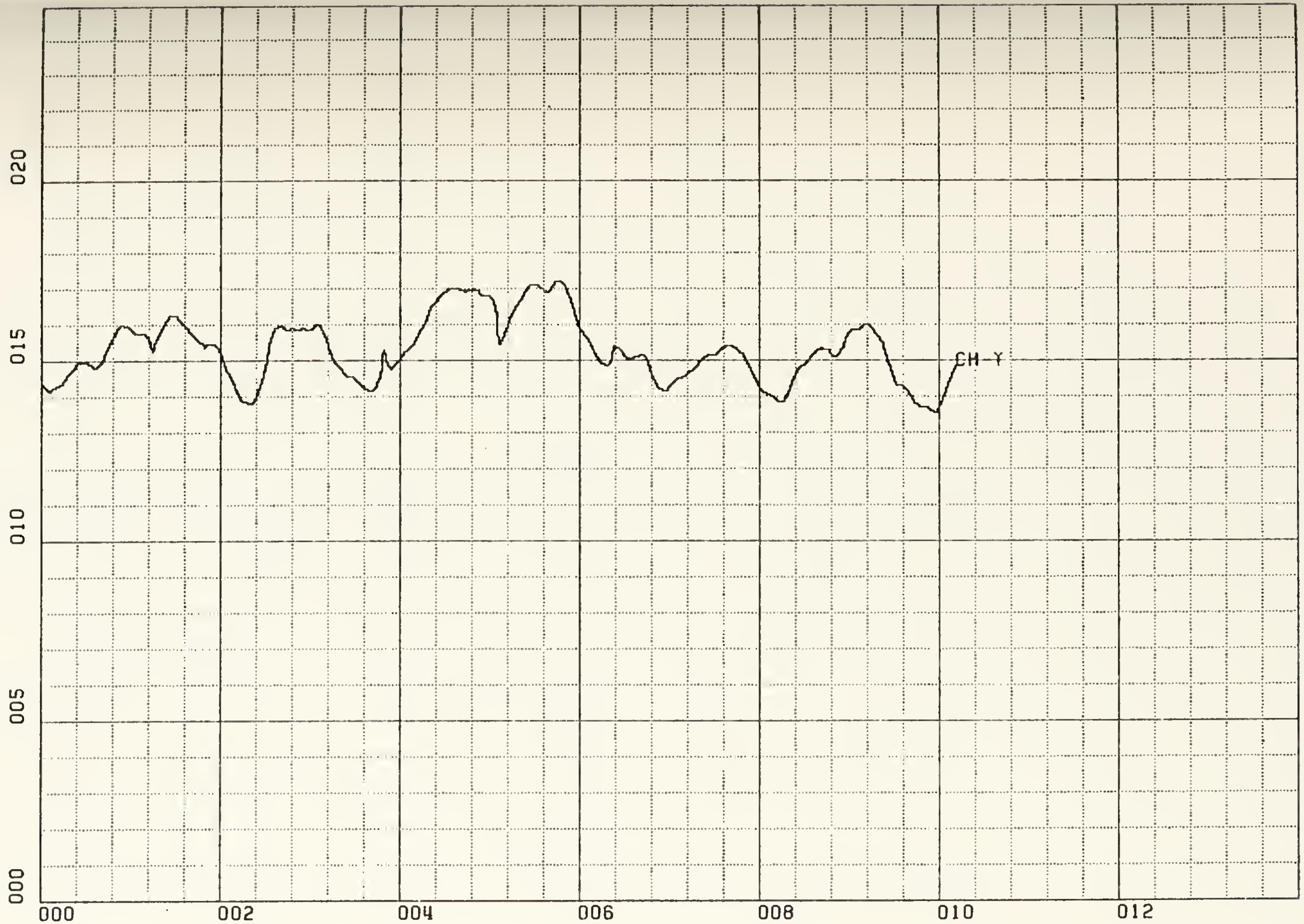

Figure 6.36 Y Coil Magnetic Field

Chew's Ridge, 1310 - 1317 Local

Field (5 nanoteslas/inch) vs Time (200 seconds/inch).

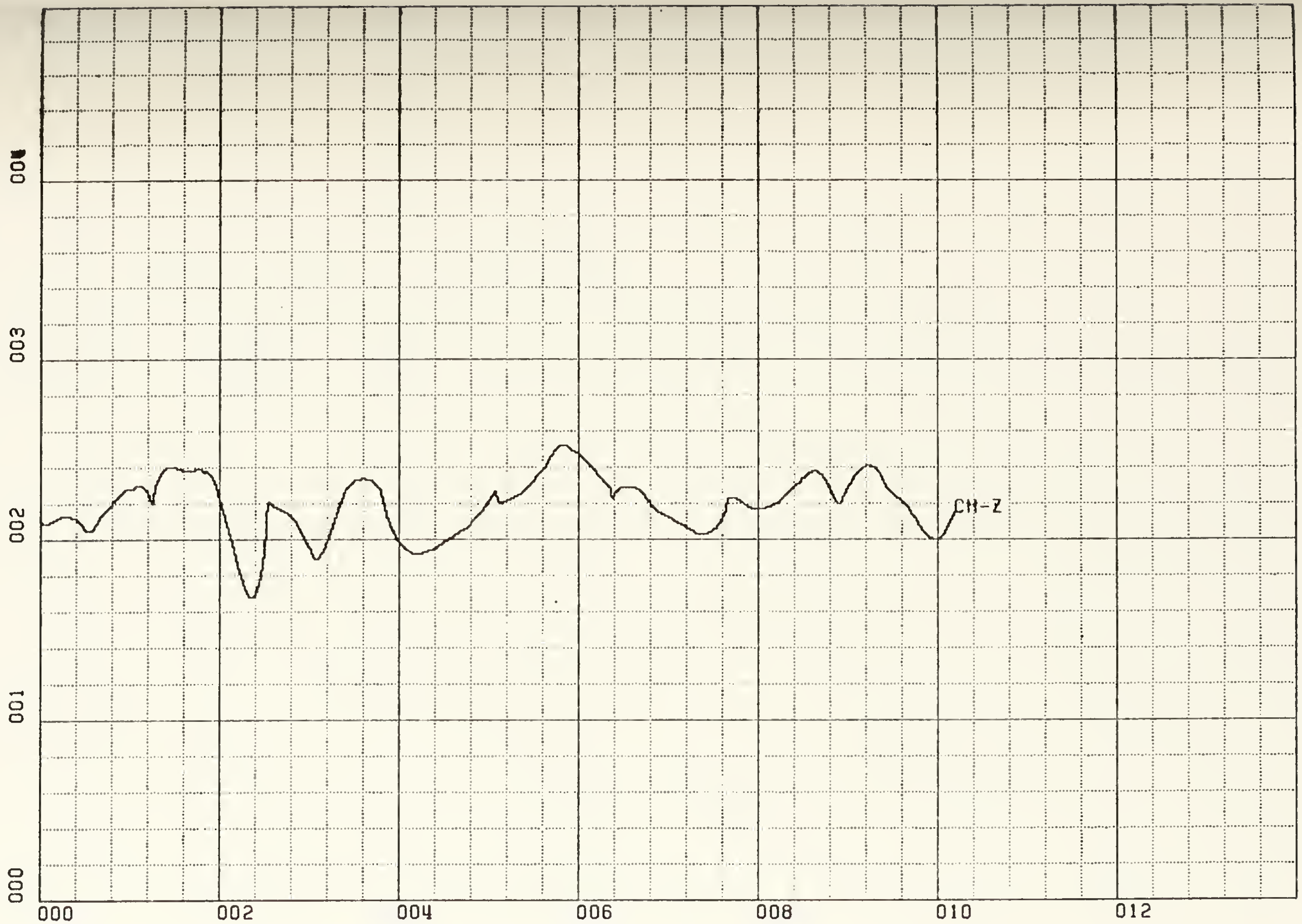

Figure 6.37 Z Coil Magnetic Field

Chew's Ridge, 1310 - 1317 Local

Field (10 nanoteslas/inch) vs Time (200 seconds/inch).

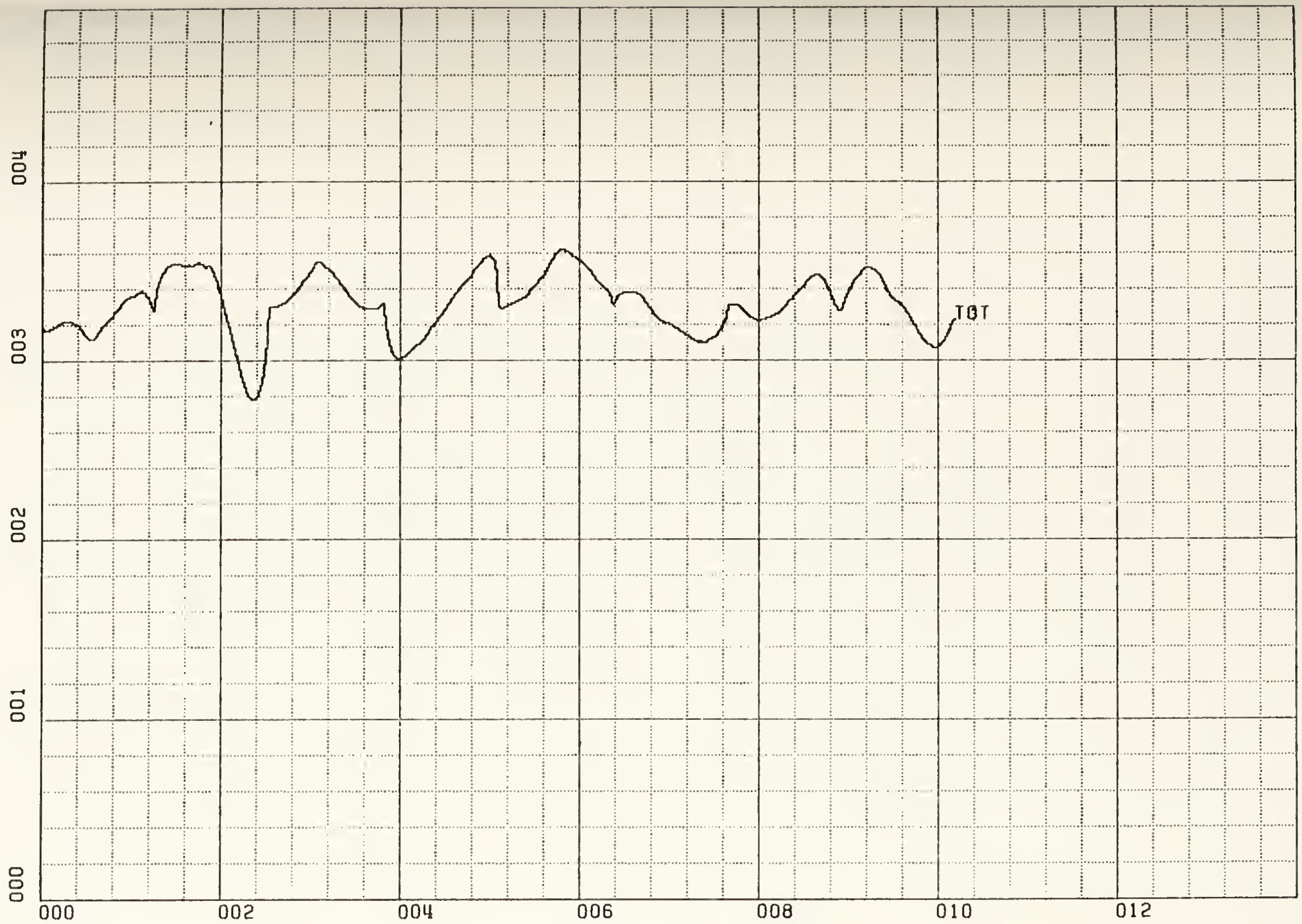

Figure 6.38 Total Magnetic Field

Chew's Ridge, 1310 - 1317 Local

Field (10 nanoteslas/inch) vs Time (200 seconds/inch).

Figure 6.39 X Coil Magnetic Field

La Mesa Village, 1515 - 1532 Local

Field (1 nanotesla/inch) vs Time (200 seconds/inch).

Figure 6.40 Y Coil Magnetic Field

La Mesa Village, 1515 - 1532 Local

Field (1 nanotesla/inch) vs Time (200 seconds/inch).

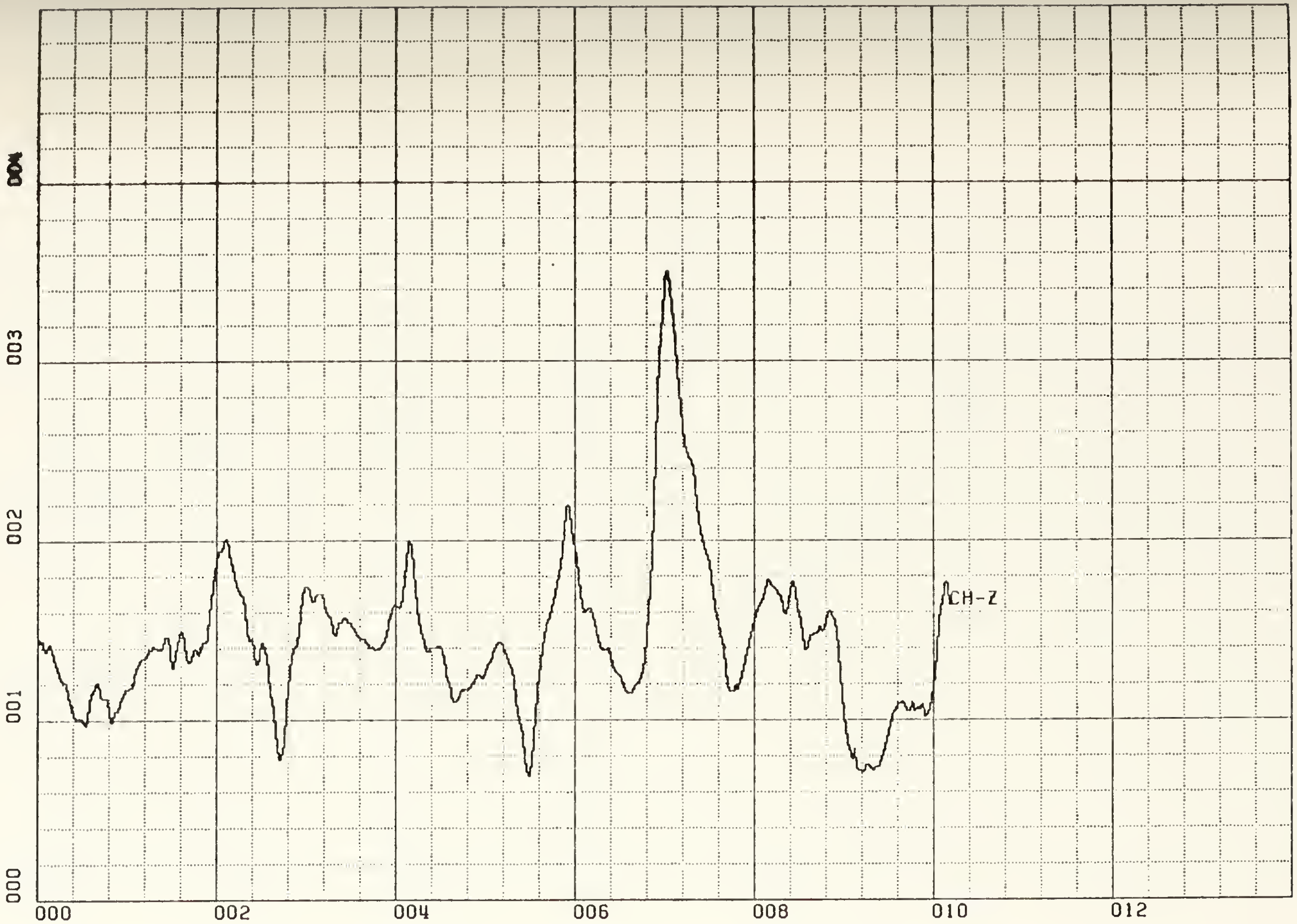

Figure 6.41 Z Coil Magnetic Field

La Mesa Village, 1515 - 1532 Local

Field (1 nanotesla/inch) vs Time (200 seconds/inch).

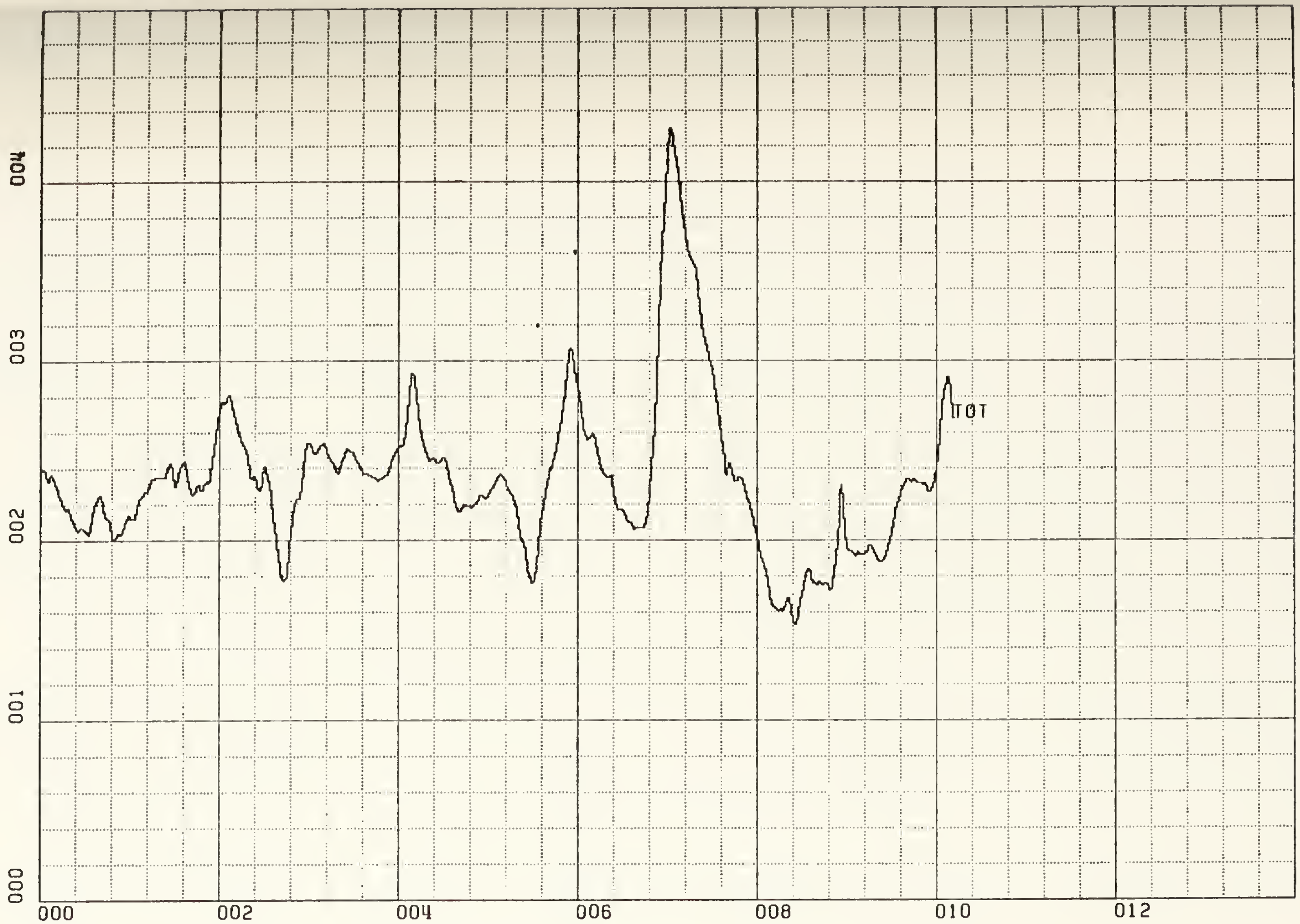

Figure 6.42 Total Magnetic Field

La Mesa Village, 1515 - 1532 Local

Field (1 nanotesla/inch) vs Time (200 seconds/inch).

Figure 6.43   X Coil Magnetic Field

La Mesa Village, 1802 - 1819 Local

Field (2 nanotesla/inch) vs Time (200 seconds/inch).

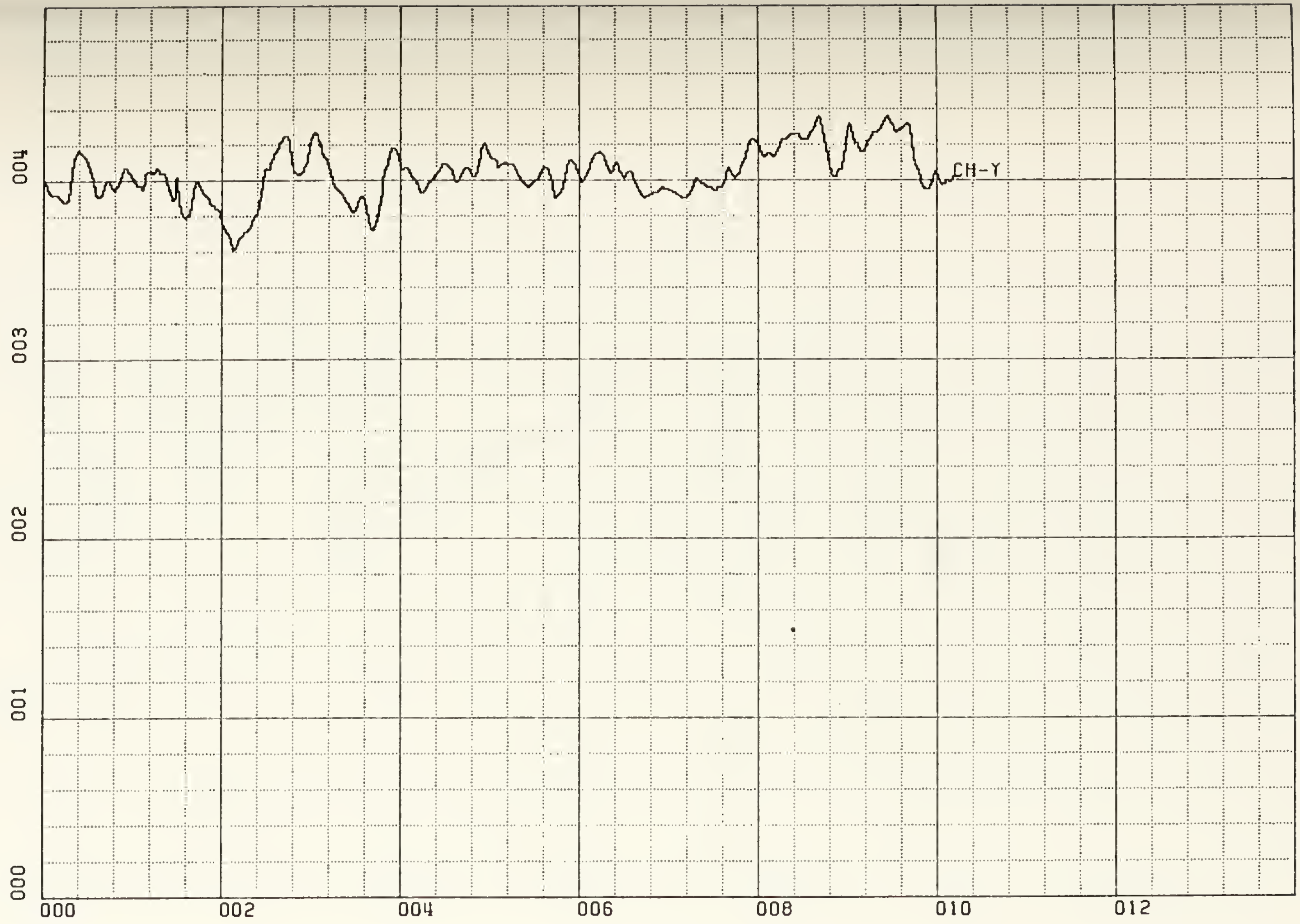

Figure 6.44 Y Coil Magnetic Field

La Mesa Village, 1802 - 1819 Local

Field (1 nanotesla/inch) vs Time (200 seconds/inch).

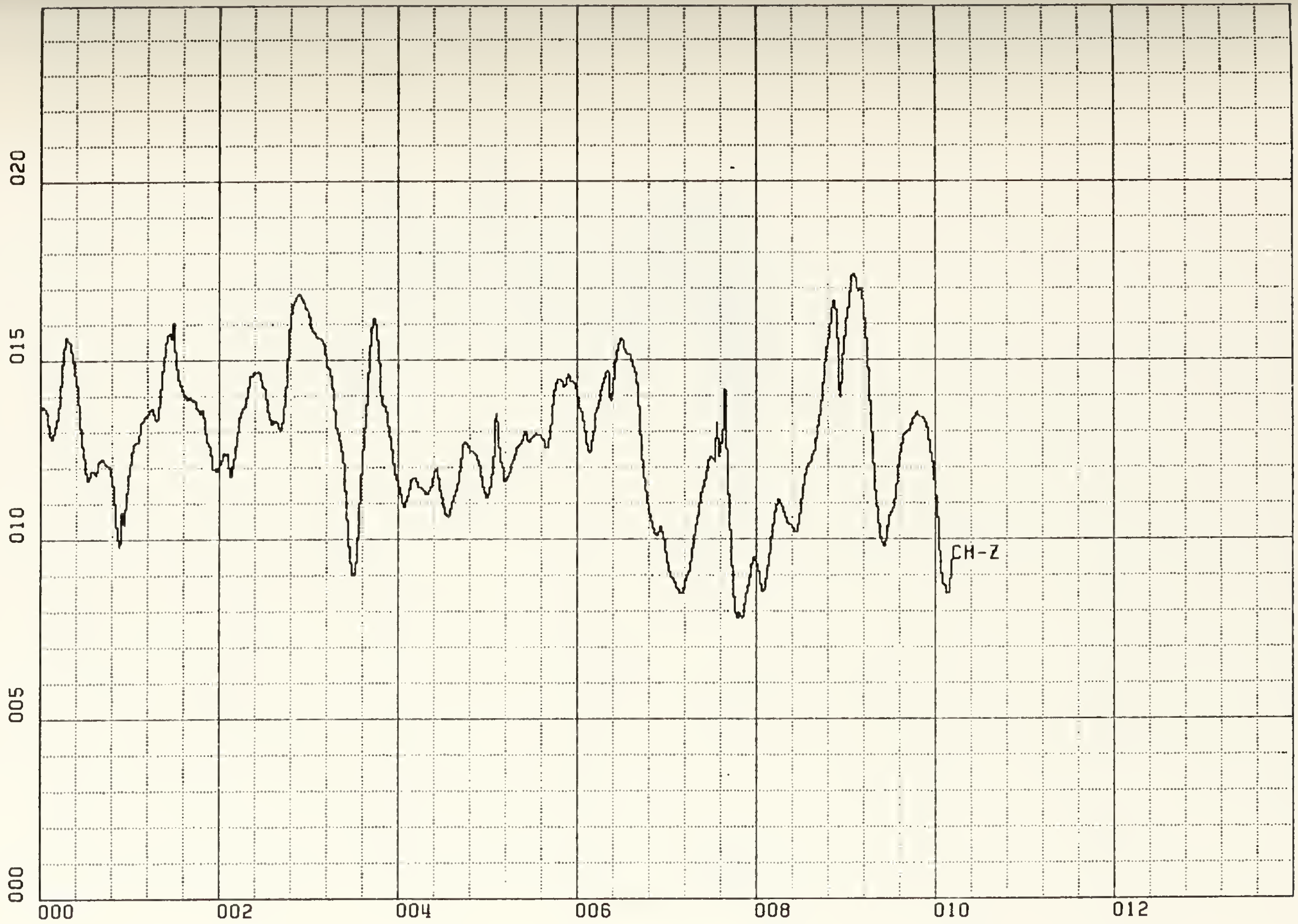

Figure 6.45 Z Coil Magnetic Field

La Mesa Village, 1802 - 1819 Local

Field (0.5 nanotesla/inch) vs Time (200 seconds/inch).

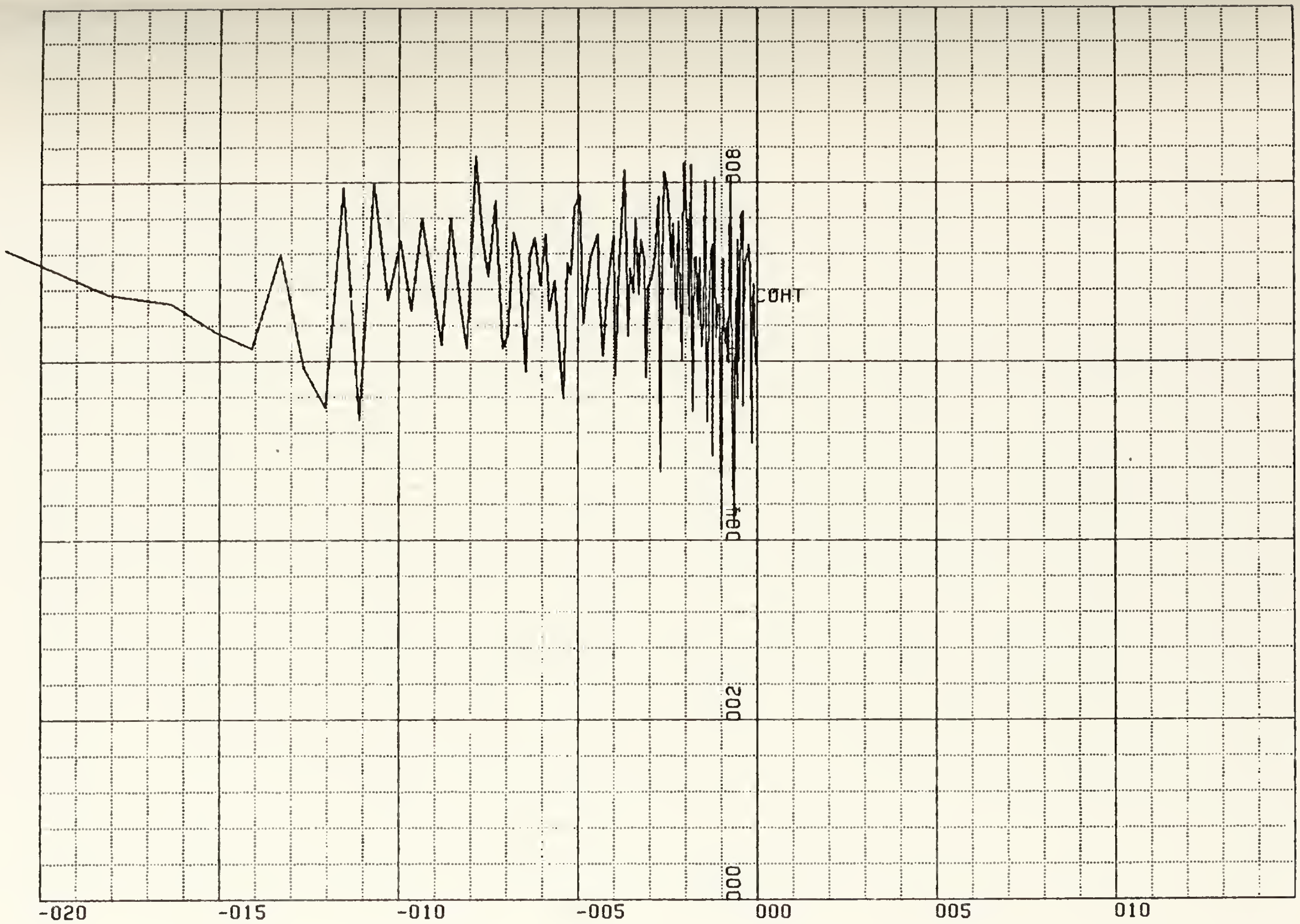

Figure 6.46 Total Field Coherence

1310 - 1350 Local

Coherence (0.2 units/inch) vs Log Frequency (0.5 Log Hz/inch).

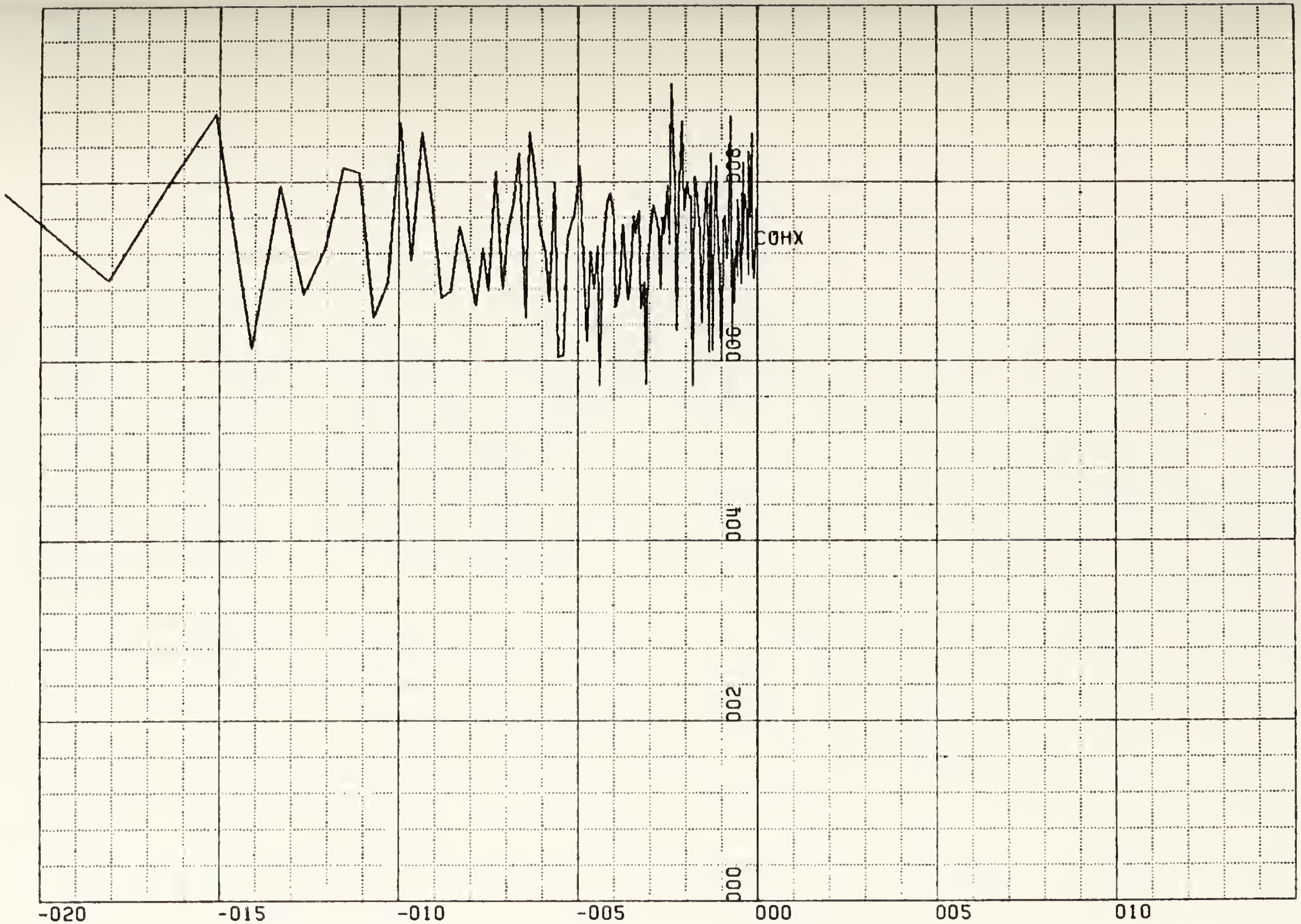

Figure 6.47 X Coil Coherence

1310 - 1350 Local

Coherence (0.2 units/inch) vs Log Frequency (0.5 Log Hz/inch).

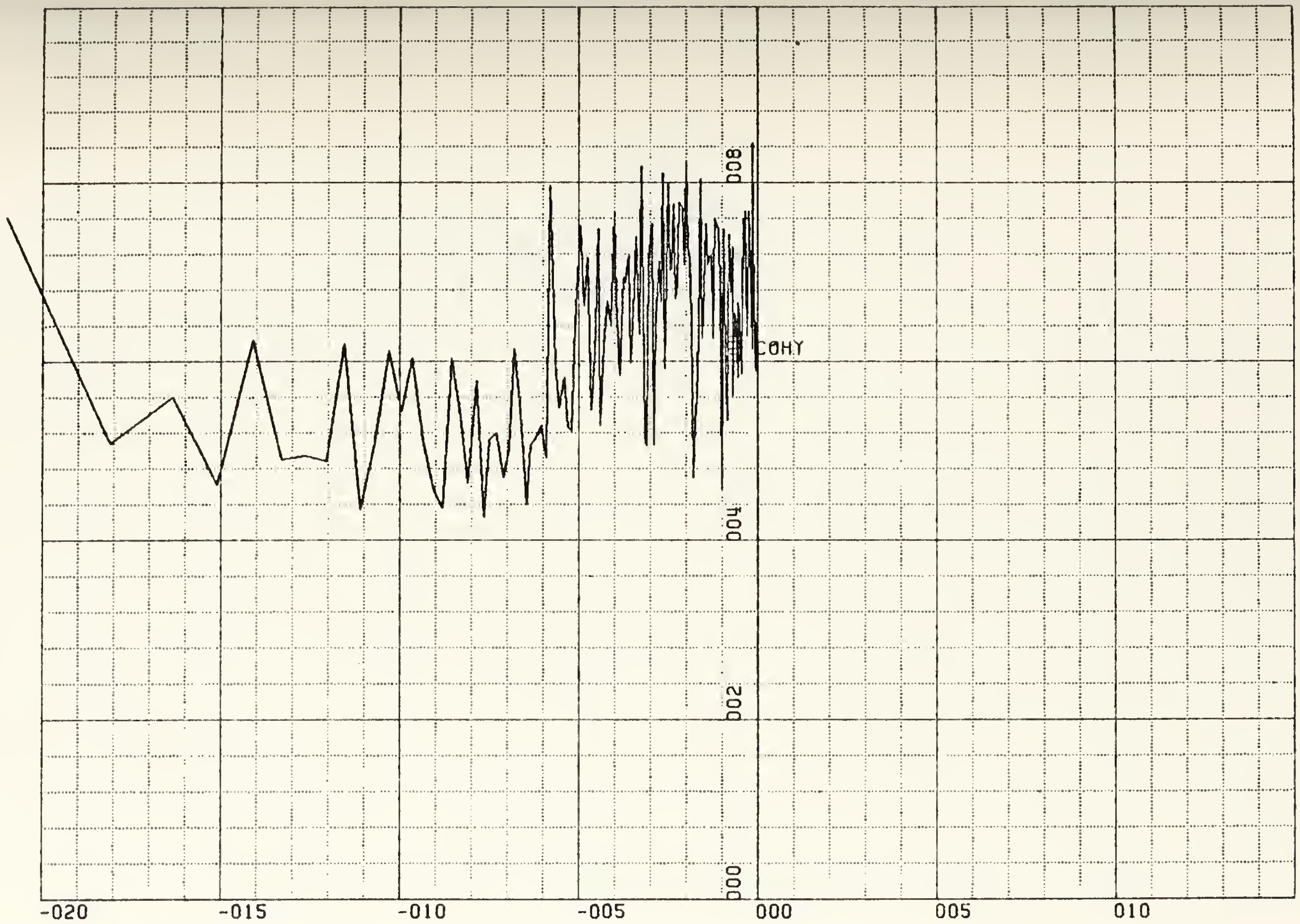

Figure 6.48 Y Coil Coherence

1310 - 1350 Local

Coherence (0.2 units/inch) vs Log Frequency (0.5 Log Hz/inch).

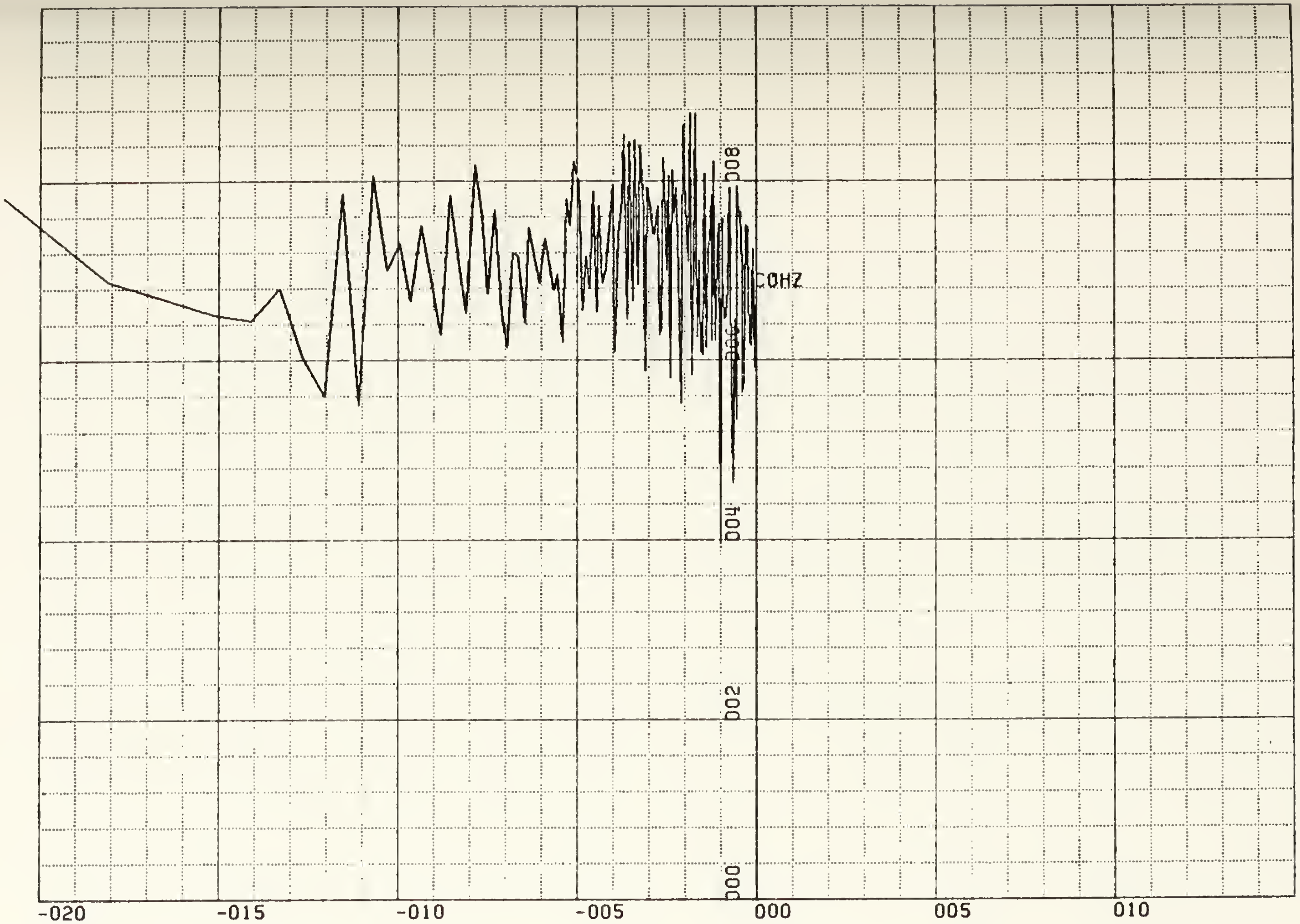

Figure 6.49 Z Coil Coherence

1310 - 1350 Local

Coherence (0.2 units/inch) vs Log Frequency (0.5 Log Hz/inch).

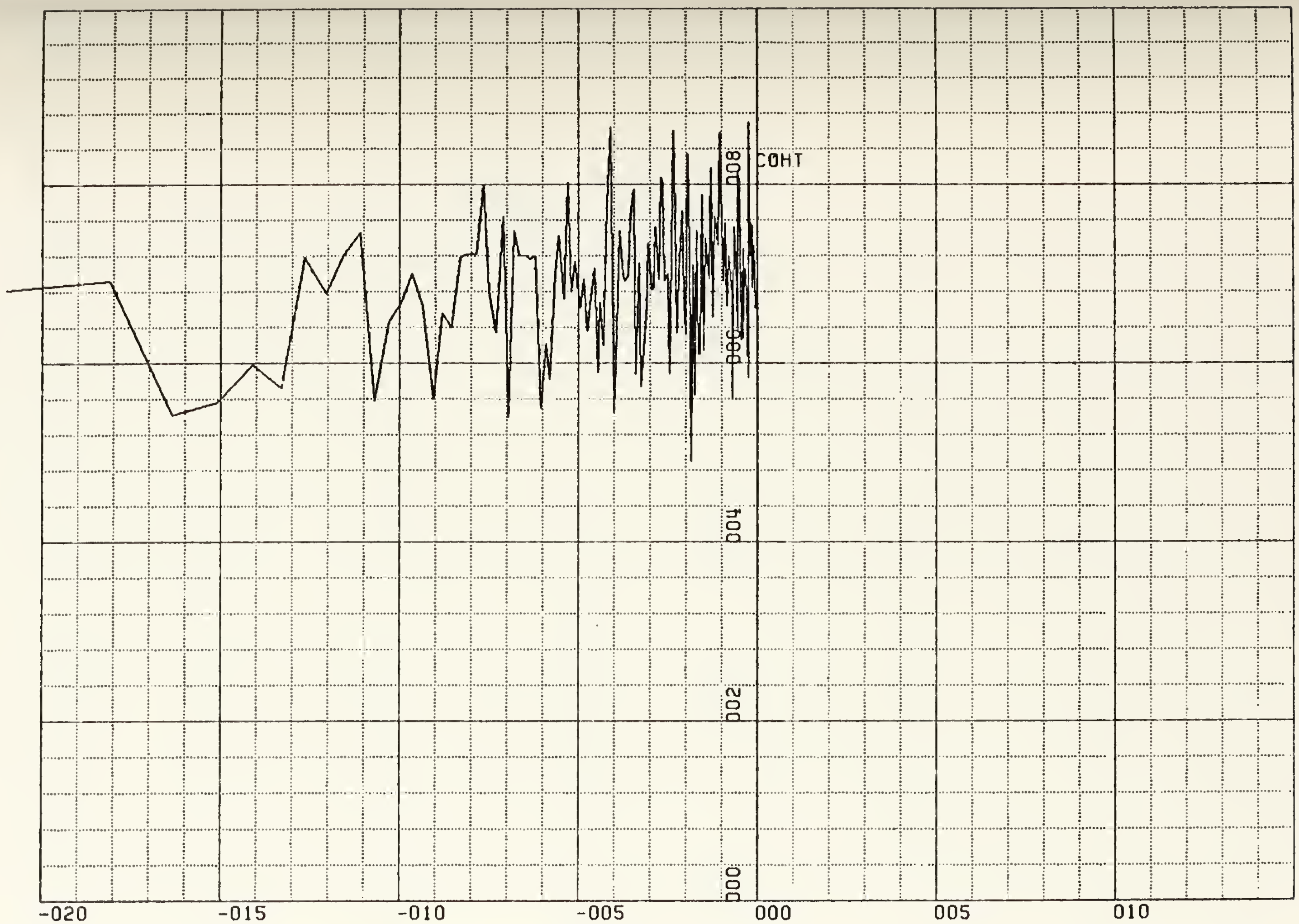

Figure 6.50 Total Field Coherence

1500 - 1540 Local

Coherence (0.2 units/inch) vs Log Frequency (0.5 Log Hz/ inch).

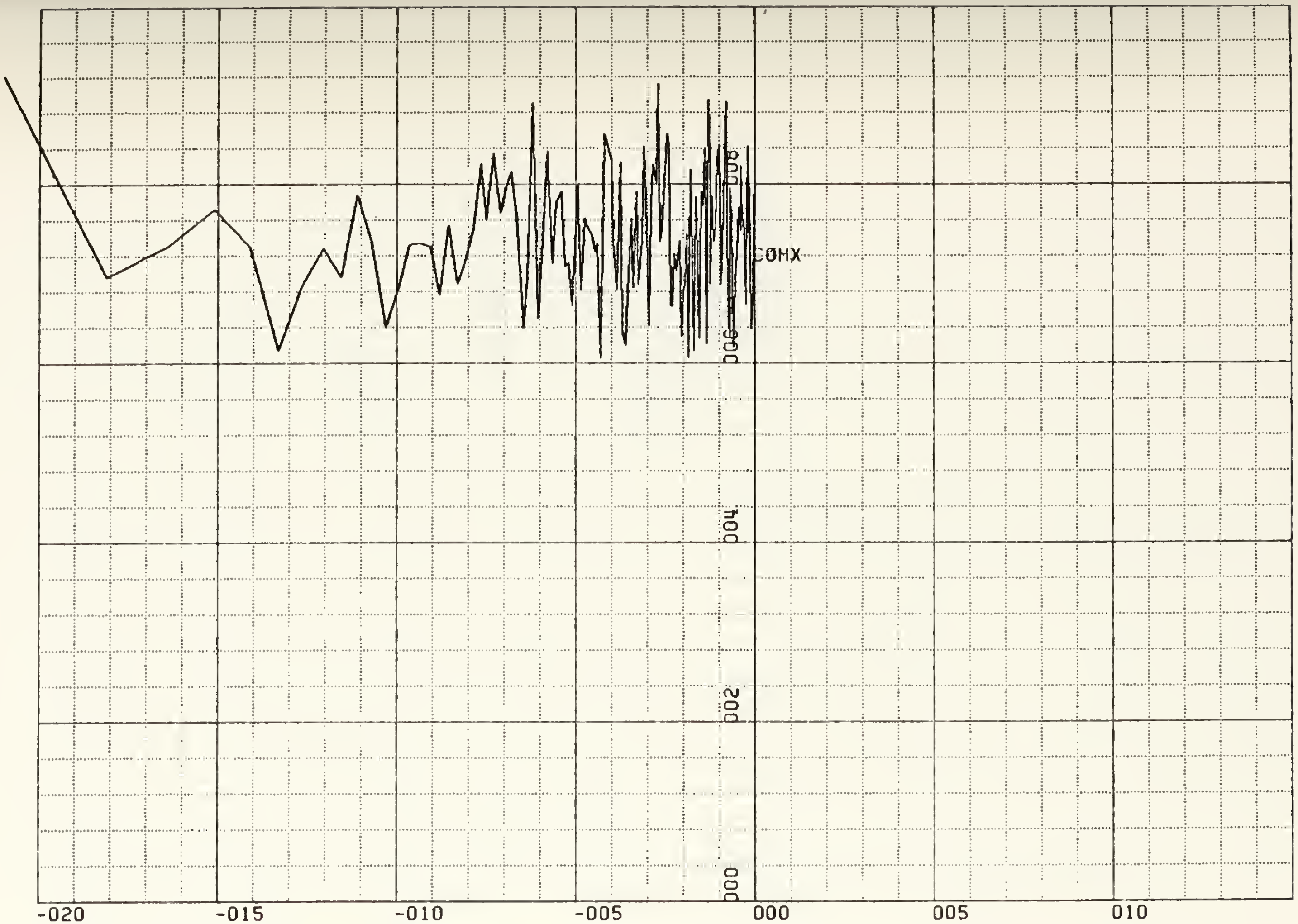

Figure 6.51 X Coil Coherence

1500 - 1540 Local

Coherence (0.2 units/inch) vs Log Frequency (0.5 Log Hz/ inch).

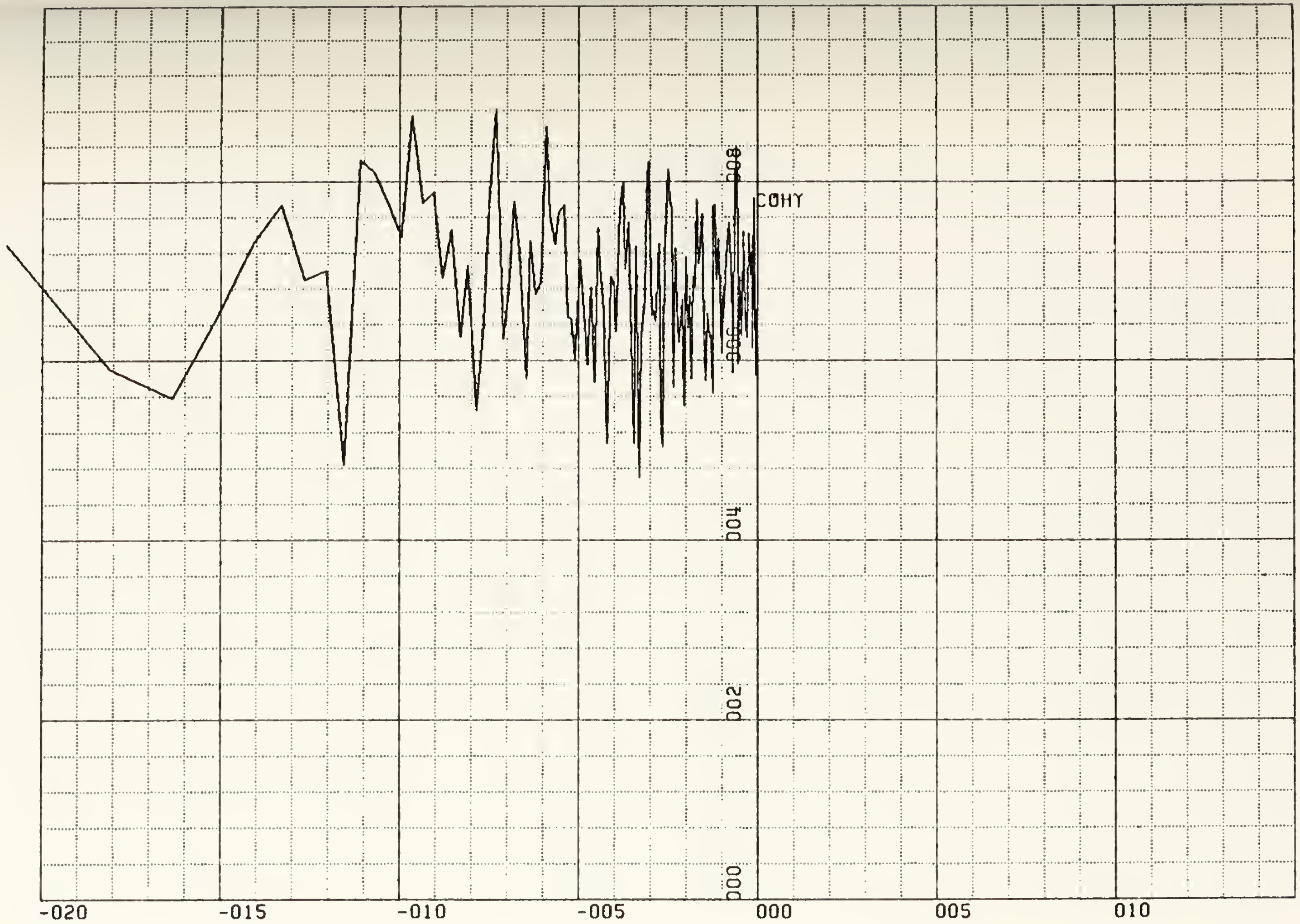

Figure 6.52 Y Coil Coherence

1500 - 1540 Local

Coherency (0.2 units/inch) vs Log Frequency (0.5 Log Hz/inch).

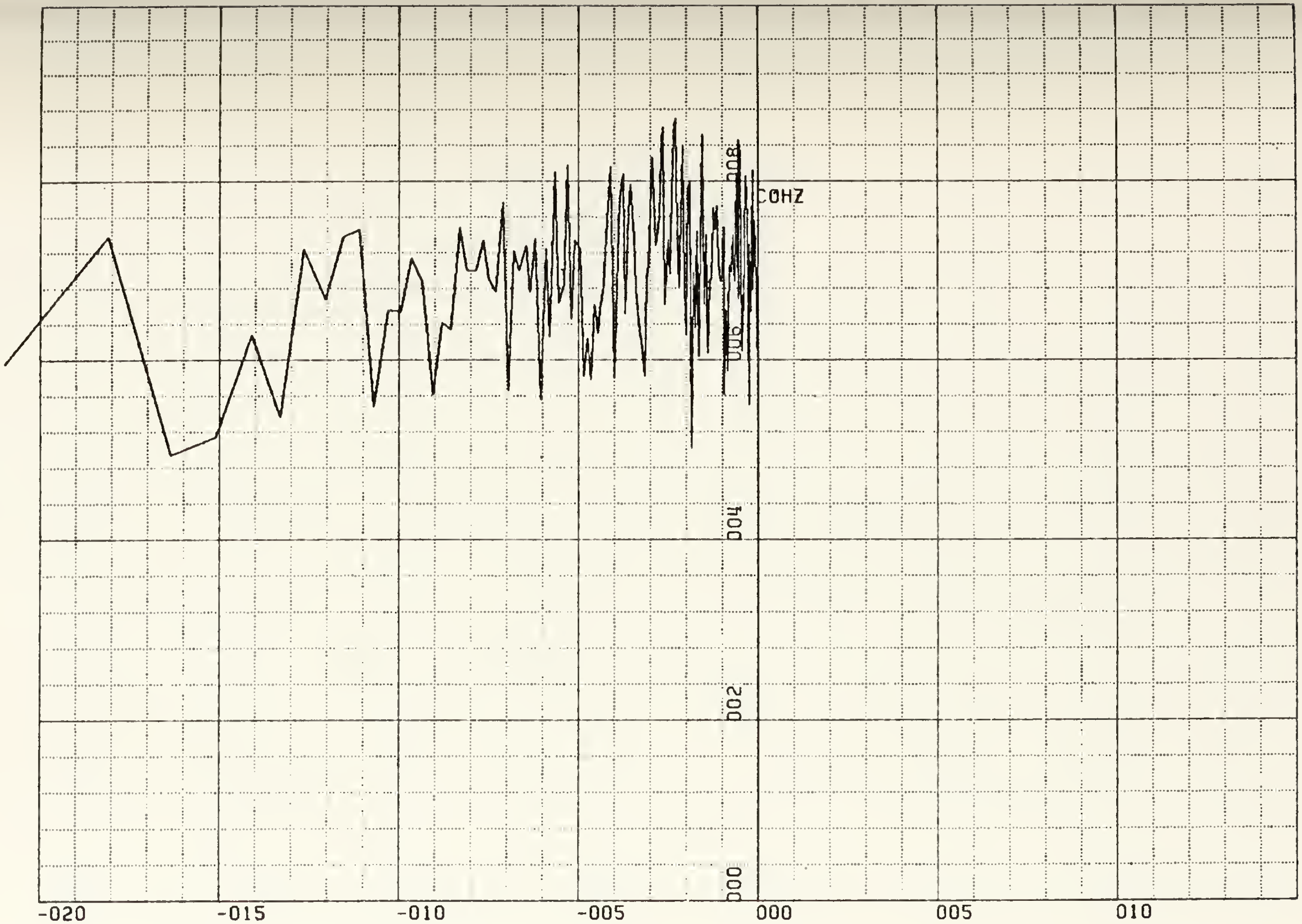

Figure 6.53 Z Coil Coherence

1500 - 1540 Local

Coherence (0.2 units/inch) vs Log Frequency (0.5 Log Hz/inch).

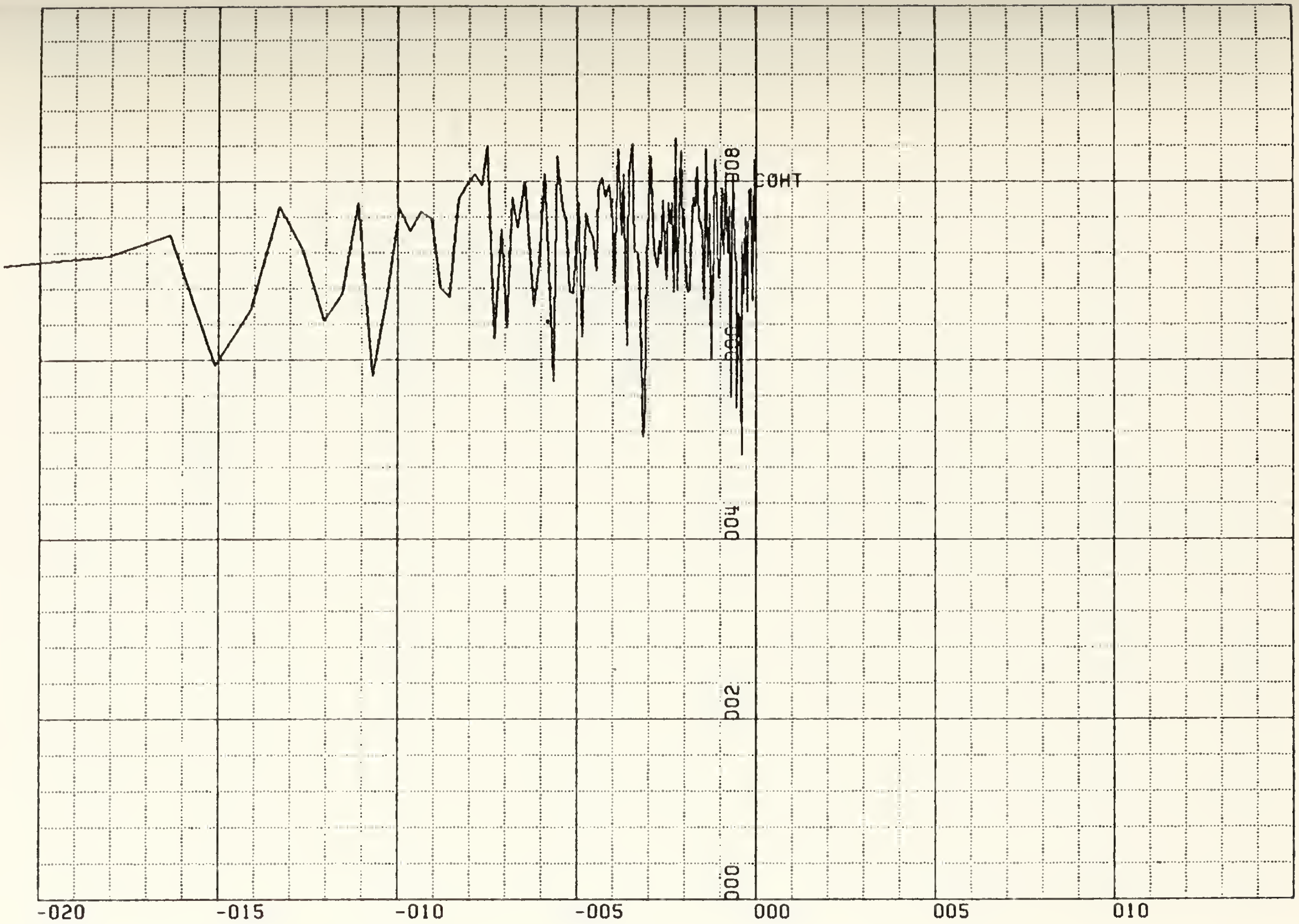

Figure 6.54 Total Field Coherence
1700 - 1740 Local
Coherence (0.2 units/inch) vs Log Frequency (0.5 Log Hz/inch).

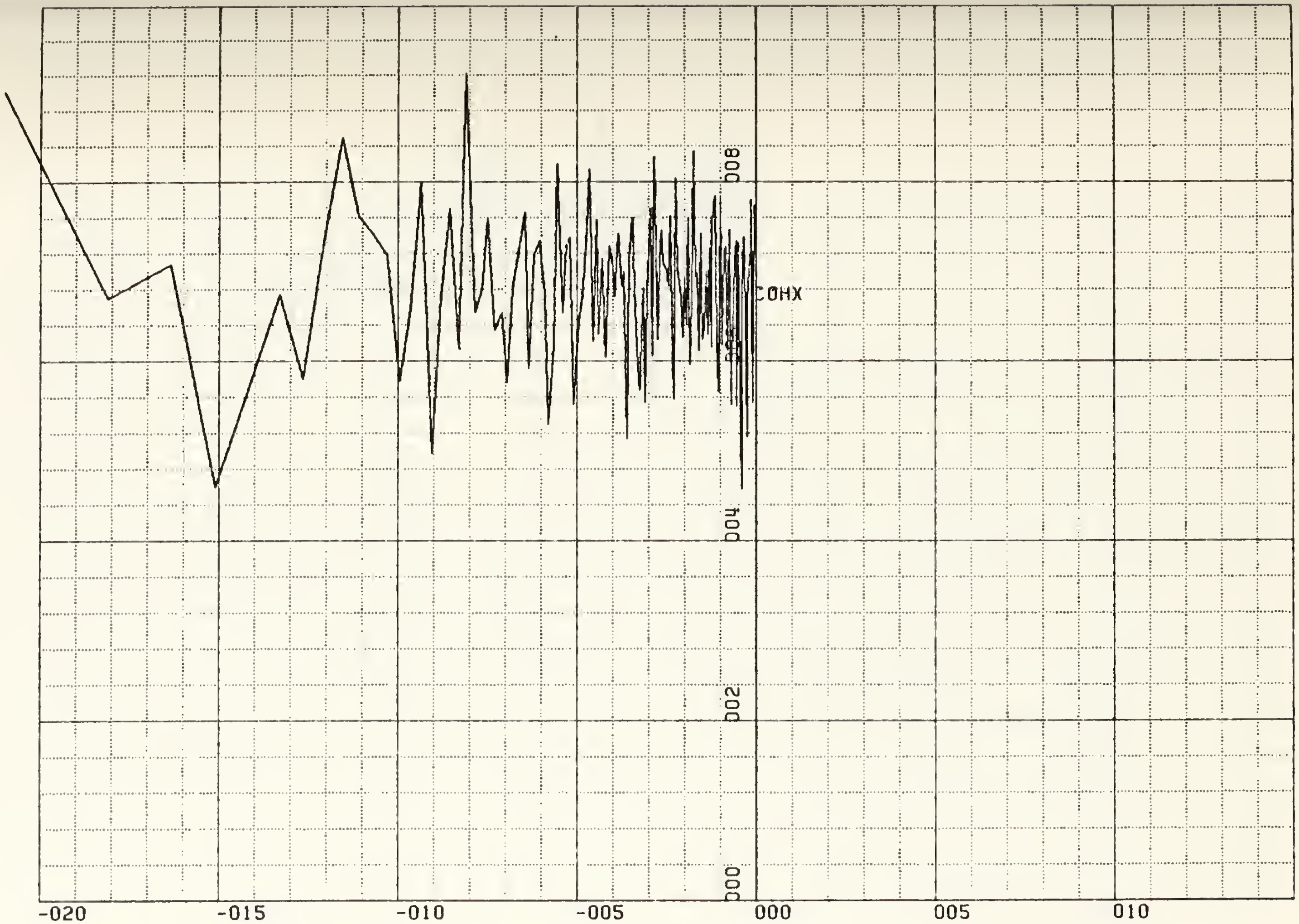

Figure 6.55 X Coil Coherence

1700 - 1740 Local

Coherence (0.2 units/inch) vs Log Frequency (0.5 Log Hz/inch).

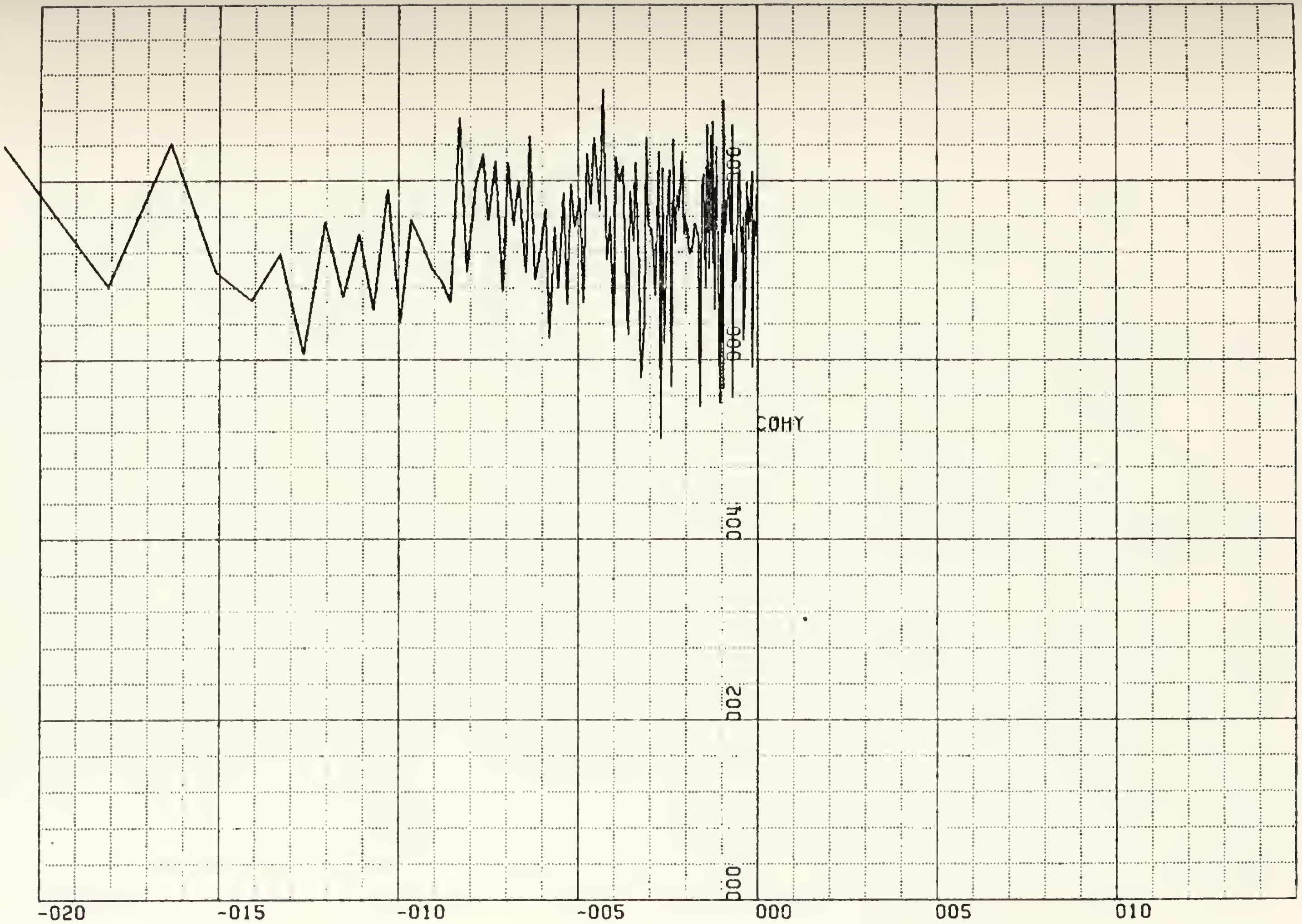

Figure 6.56 Y Coil Coherence

1700 - 1740 Local

Coherence (0.2 units/inch) vs Log Frequency (0.5 Log Hz/inch).

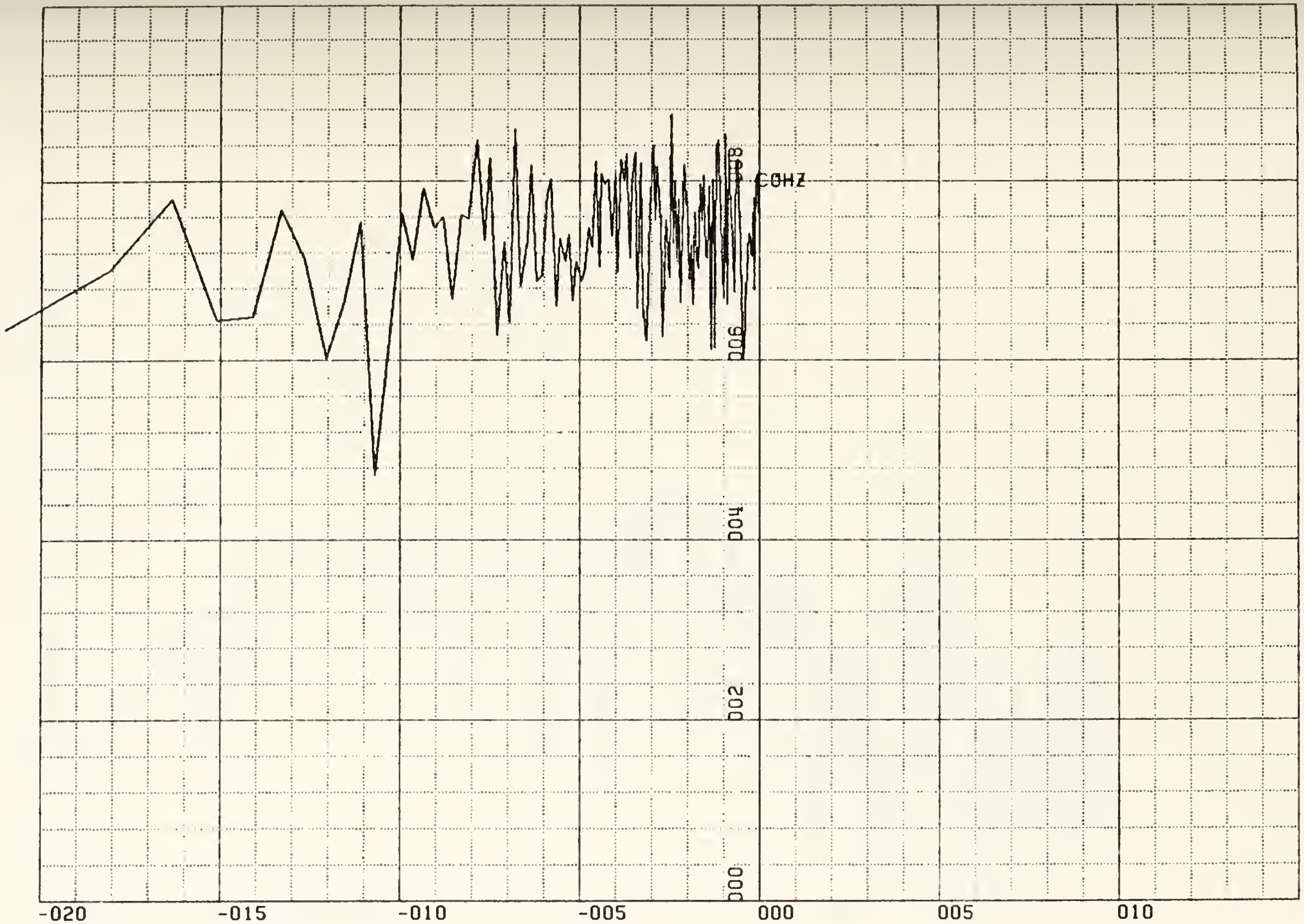

Figure 6.57 Z Coil Coherence

1700 - 1740 Local

Coherence (0.2 units/inch) vs Log Frequency (0.5 Log Hz/inch).

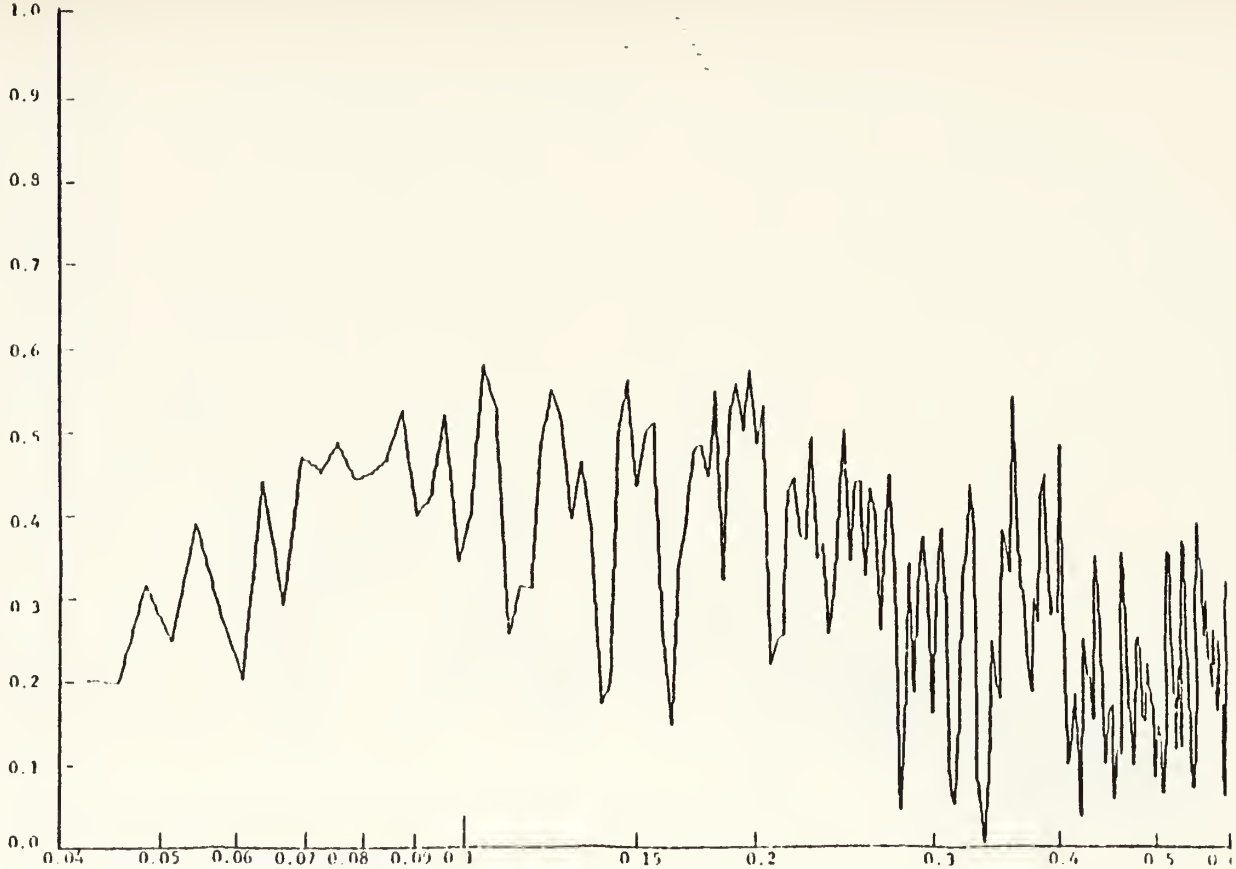

Figure 6.58 Total Field Coherence, NADC

11 July 1979, 1430 - 1630 Local

Coherence vs Frequency

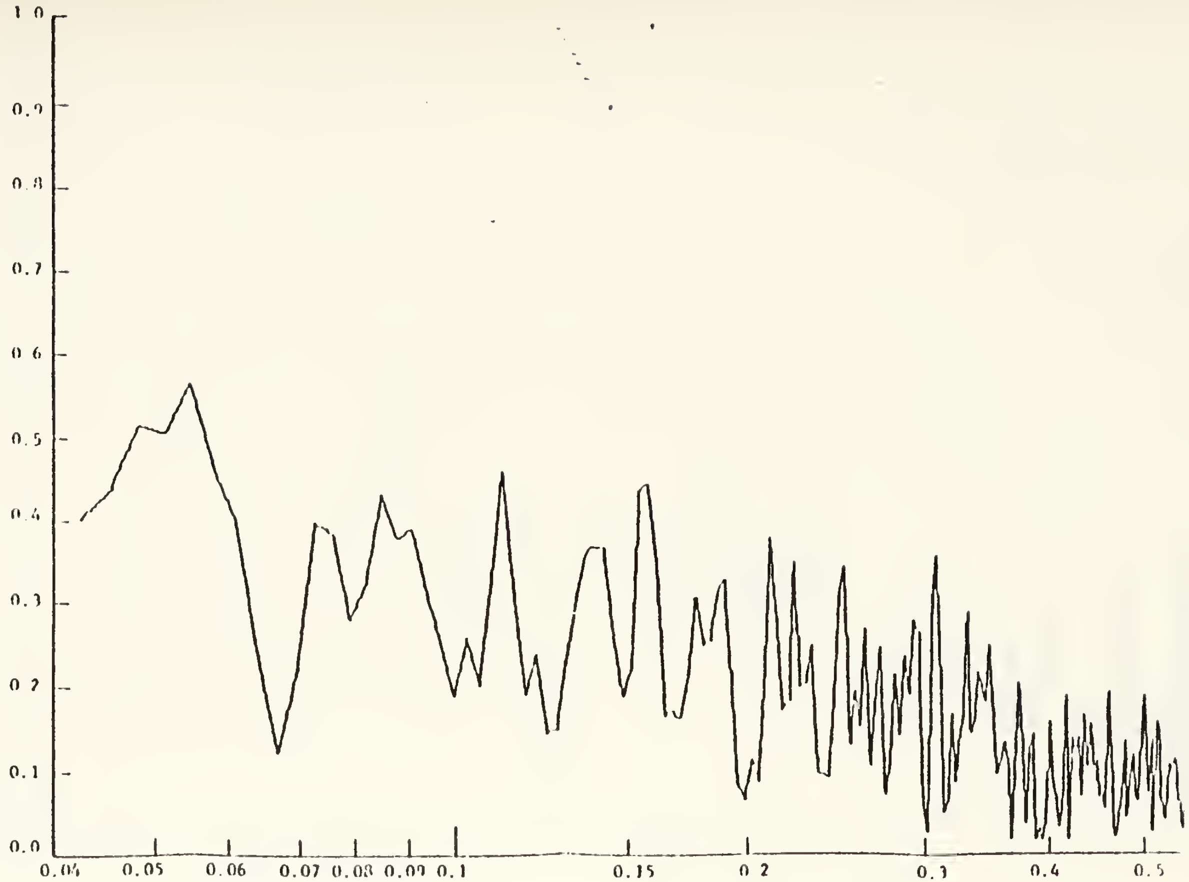

Figure 6.59 Total Field Coherence, NADC

11 July 1979, 1700 - 1900 Local

Coherence vs Frequency

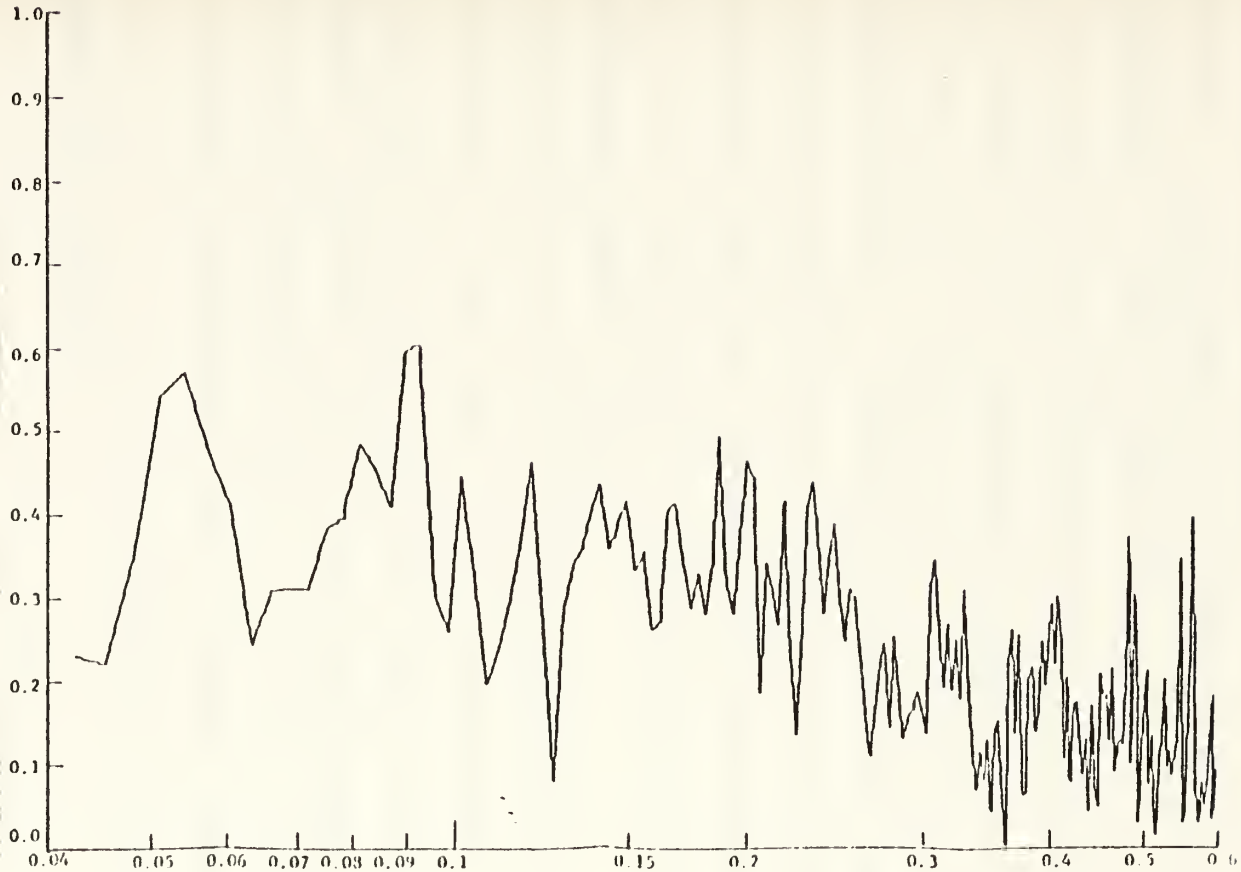

Figure 6.60 Total Field Coherence, NADC

11 July 1979, 1915 - 2115 Local

Coherence vs Frequency

VII. CONCLUSIONS AND RECOMMENDATIONS

A coherence of 0.6 - 0.8 in the background component of the geomagnetic field between 0.04 and 0.6 Hz was established. A coherence in this range should be considered only moderate. A lack of high coherence (0.9 - 1) indicates that the variations in the background field observed at the earth's surface at the two sites are not produced directly by the same source. However, the variations are clearly not random in nature. The moderate coherences found suggest that the source mechanisms for the background component in the geomagnetic field are complex and involve mechanisms in addition to or intermediate to simple fluctuations in the interplanetary magnetic field.

A discernable micropulsation was not recorded during the five hours of data taken. It is recommended that additional data be taken at the two sites in the hope of performing a coherence study on the micropulsation component of the geomagnetic field. It is also recommended that data be taken at additional sites of greater separation (100 km or more) in order to investigate the degree of coherence with distance.

APPENDIX A

SITE DESCRIPTION

The Chew's Ridge fire lookout is located 40 km southeast of the Naval Postgraduate School and at an altitude of approximately 3900 feet above sea level. It was chosen for its remoteness from the local power grid. Since the site is within the Los Padres National Forest, permission to collect data there had to be obtained from the National Forest Service. A dirt road provides easy access to the site for the transporting of equipment. The Monterey Institute for Research in Astronomy is currently constructing an observatory approximately one half mile from the lookout. What affect its presence will have on the suitability of the fire lookout for future data collection is not currently known.

Initial attempts to transmit the PCM data via a 170 MHz carrier wave from this site to the school proved impossible due to the relatively low transmission power used (3 watts), less than ideal line of sight, less than ideal antenna.

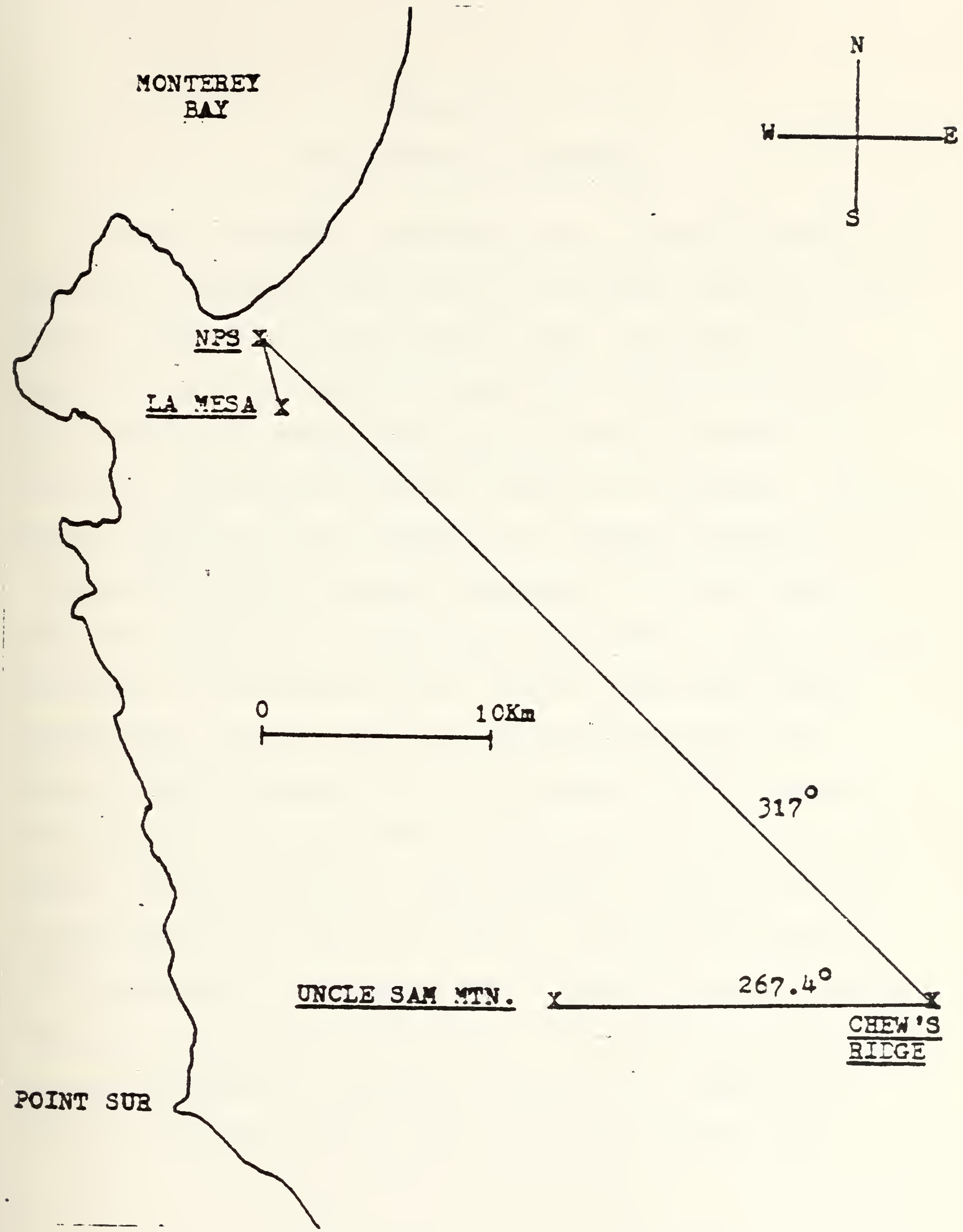

Figure A.1 Geographical Area of Data Collection.

APPENDIX B

PCM DECODING PROCEDURE

Several electronic components are utilized to decode the PCM data to digital form which is ultimately stored on nine track, 800 bits per inch digital tape. This data processing system is shown in Figure B.1. Central control of this process is accomplished with a Hewlett Packard 9845A computer utilizing an operator interactive program, "PCMPROG". After execution of the program, the computer requests entry of specific function control parameters into the computer and other equipment. These inputs are used to control synchronization of equipment start, digital tape drive speed, decode rate, decode time and synchronization code word entry into the decoder. The PCM encoded data is fed into the system from the HP 3964A/3968A tape recorder previously used to record the data. The decoding of the PCM data is accomplished with a Marine Profiles, Incorporated Model 319 PCM decoder. A Monsanto AM-6419/USM-368 oscilloscopes are used to display the PCM data. A Kennedy Model 9800 digital recorder and computer interface are employed to store the digital data on the nine track digital tape.

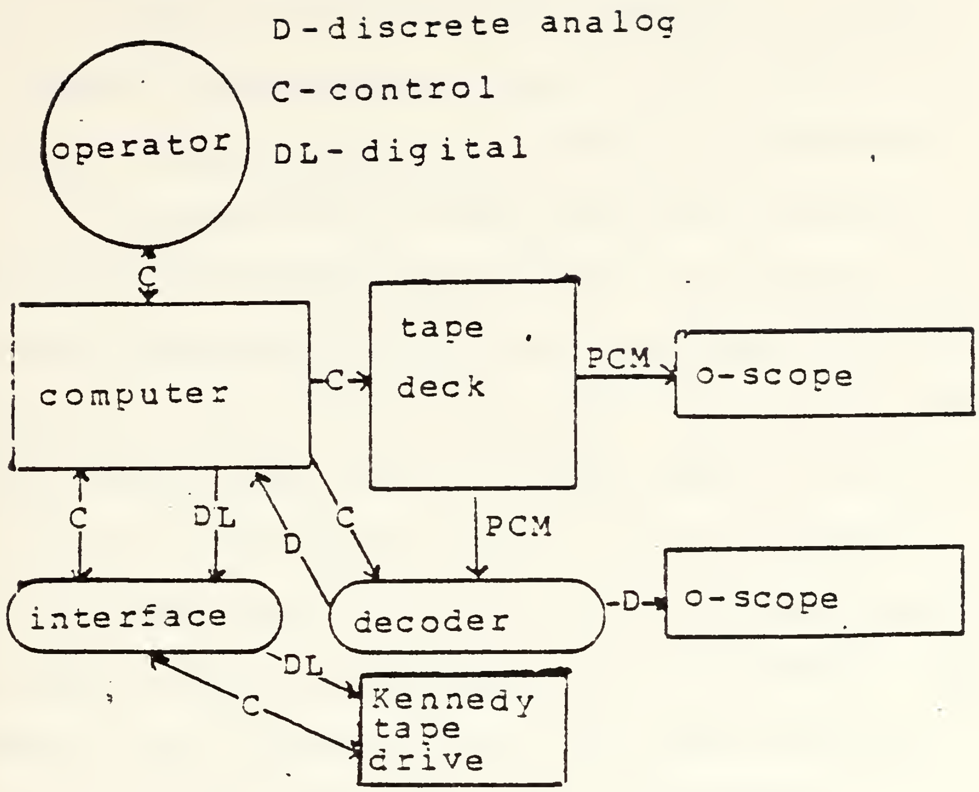

Figure B.1 Decoding System Data Flow and Control.

1. <u>Decoding Procedure</u>

a. Connect a coaxial cable between the output channel desired for decoding of the HP 3964A/3984A tape recorder and channel three of the Model 319 PCM decoder.

b. Energize the HP 3964A/3984A tape recorder, the Monsanto AM-6419/USM-368 oscilloscope, the Kennedy interface and the AANDERAA tape transfer interface, the Model 319 PCM decoder and the HP 9845A computer. Also, on the PCM Model 319 decoder place the fan toggle switch in the UP position and the AC/DC/OFF switch in the AC position.

c. Place into the right hand side tape reader of the HP 9845A computer the program named "PCM PROG". Type the command "MASS STORAGE IS":T15" and press EXECUTE. Then type the command GET "MT" and press EXECUTE.

d. On the PCM decoder place the following functions to the listed positions:

SOURCE - 3

SAMPLE RATE - 64 (for 3 3/4 recorder speed)

INVERT/NORMAL - NORMAL

OUTPUT/SAMPLE RATE - 0

RECORDS/FILE - INFINITY

SYNC CODE - 000

e. Press RUN on the computer, ignore the computer's response "enter Y to skip tape init" and press CONTINUE.

f. The computer now indicates "load tape" into the Kennedy unit and "put on line". To do this energize the Kennedy unit, place a write ring on the digital tape and load the tape according to the diagram located on the inside of the unit's door, press the LOAD button and the ON-LINE button located on the front of the unit.

g. The computer now indicates "enter synch code". Type into the computer 3658 (Chew's Ridge tapes) or 3155 (La Mesa Village tapes) and press CONTINUE.

h. Enter transfer time in minutes and seconds into the computer. For example 30 minutes and 50 seconds would be typed in as 30,50. Most analog tapes lasted 45 - 50 minutes. After this is done, press CONTINUE.

i. Push the STOP switch on the PCM decoder and press CONTINUE on the computer.

j. Push the PLAY button on the Hewlett Packard tape recorder, listening to the WWV time signal over a speaker or headphones. Push the START switch on the PCM decoder to begin the decoding process at a chosen time, using the second "ticks" of the time signal as a count-down. The decoding of the corresponding analog tape from the other recording site must be started at precisely the same time.

k. To end the data transfer early, push the K0 button on the computer. If this option is selected, "T" must be entered on the computer to write end of file on the digital tape.

l. "End of run" will be indicated on the computer CRT. Deenergize the equipment.

APPENDIX C

VOLTR COMPUTER PROGRAM

```
//CHFI19R JOB (2992,0165),'ANTHONY    SMC 2123',CLASS=G
//*MAIN ORG=NPGVM1.2992P,LINES=(65)
//*FORMAT PR,DDNAME=PLOT.SYSVECTR,DEST=LOCAL
// EXEC FRTXCLGP,PARM.LKED='LIST,MAP,XREF',REGION.GO=2048K
//FORT.SYSIN DD *
C
C     THIS PROGRAM GENERATES ROUGH VOLTAGE VS TIME PLOTS.  THE DATA IS
C     READ FROM A COMPUTER TAPE IN BLOCKS CONTAINING 8192 SAMPLES, OR
C     128 SECONDS, OF DATA.
      INTEGER*2 IN(16)
C       ARRAY 'IN' IS USED IN READING DATA FROM TAPE
      REAL*4 XX(8192),YY(8192),ZZ(8192)
C       THE ABOVE REAL*4 ARRAYS ARE USED TO ORDER INPUT DATA AND
C       INITIALLY REPRESENT VOLTAGE - TIME SERIES INFORMATION.
      DIMENSION ZZX1(65536),ZZY1(65536),ZZV1(65536)
      DIMENSION TIME2(65536)
      INTEGER K,I5
      INTEGER*4  ITB(12)/12*0/
      REAL*4     RTB(28)/28*0.0/
      REAL ALAB(3)/'CH-X','CH-Y','CH-Z'/
      REAL*8 TITLE(12)
      EQUIVALENCE(TITLE(1),RTB(5))
C       ARRAYS 'ITB','RTB','ALAB',AND 'TITLE' ARE USED IN GENERATING
C       THE VERTSATEC PLOTTER OUTPUT.
      DATA XX,YY/16384*0./
      DATA ZZ/8192*0./
      K=0
      I5=1
      DO 31 IN1=1,65536
      ZZX1(IN1)=0.0
      ZZY1(IN1)=0.0
      ZZV1(IN1)=0.0
      TIME2(IN1)=0.0
   31 CONTINUE
C        THE NEXT FIVE LINES SERVE AS A TIME DELAY IN STARTING THE
C        DATA ANALYSIS. ISEC IS THE NUMBER OF SECONDS DELAYED.
      ISEC=10
      ITL=ISEC*64
      DO 55 JJ=1,ITL
      CALL RD(20,IN,200,IREC,IRR)
   55 CONTINUE
      IFRAME=8192
C       THE VALUE OF NR DETERMINES THE NUMBER OF DATA BLOCKS THE ARE
C       READ AND ANALYZED.
      NR=8
      FNR=FLOAT(NR)
      DO 70 L1=1,NR
C       THE DO LOOP ENDING WITH STATEMENT 70 ENABLES THE PROGRAM TO
```

```
C        PROCESS A LARGE AMOUNT OF DATA BY REPEATING THE PROCESS IN
C        BLOCKS.
C        'NR' REPRESENTS THE NUMBER OF DATA SEQUENCES. ONE
C        SEQUENCE CURRENTLY EQUALS 8192 DATA POINTS FOR EACH CHANNEL
C        OR 128 SECONDS OF DATA.
C
C         THE DO LOOP ENDING WITH 60 READS THE DATA FROM THE PCM FRAME
C         STRIPS OUT THE SYNC CODE, AND SORTS OUT THE DATA BY COIL
C         CHANNEL.
      DO 60 JJ=1,IFRAME
      CALL RD(20,IN,1000,IREC,IRR)
      XX(JJ)=IN(2)
      YY(JJ)=IN(3)
      ZZ(JJ)=IN(4)
   60 CONTINUE
      N=8192
      FN=FLOAT(N)
      DELTAT=1./64.
      DO 20 J=1,N
C     THE FOLLOWING CALCULATIONS NORMALIZE THE DATA TO +5V AND -5V.
      XX(J)=((XX(J)-2048.)*5./2048.)
      YY(J)=((YY(J)-2048.)*5./2048.)
      ZZ(J)=((ZZ(J)-2048.)*5./2048.)
C        'XX' IS THE X-COIL DATA, 'YY' IS THE Y-COIL DATA,
C        'ZZ' IS THE Z-COIL DATA
C        NORTH-SOUTH COMPONENT (XX) AND THE VERTICAL COMPONENT (ZZ)
   20 CONTINUE
C        THE FOLLOWING LOOP PUTS THE DATA FROM EACH 8192-SAMPLE ARRAY
C        INTO ONE CONTINUOUS NR*8192 SAMPLE ARRAY
      DO 91 I3=1,8192
      ZZX1(I5)=XX(I3)
      ZZY1(I5)=YY(I3)
      ZZV1(I5)=ZZ(I3)
      TIME2(I5)=(DELTAT*FLOAT(I3))+(128.0*FLOAT(K))
      I5=I5+1
   91 CONTINUE
      K=K+1
   70 CONTINUE
C
C    VERSATEC PLOT OF V - TIME SERIES VOLTAGE
C
      NPTS=1020./DELTAT +1.
C        'NPTS' DETERMINES NUMBER OF POINTS NECESSARY IN ORDER FOR
C         THE 0 TO NPTS  SECS RANGE TO BE PLOTTED.
C        FOR THE FOLLOWING 'ITB' AND 'RTB' VALUES REVIEW THE WRITE-UP
C        FOR THE SUBROUTINE PROCEDURE 'DRAWP'.
      ITB(3)=20
      ITB(4)=8
```

```
      ITB(7)=1
      ITB(12)=0
      RTB(1)=0.0
      RTB(2)=0.0
      RTB(3)=ALAB(1)
      READ(5,3000)TITLE
      CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)
      RTB(3)=ALAB(2)
      READ(5,3000)TITLE
      CALL DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)
      RTB(3)=ALAB(3)
      READ(5,3000)TITLE
      CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
      ITB(3)=7
      ITB(4)=5
      ITB(12)=0
      RTB(3)=ALAB(1)
      READ(5,3000)TITLE
      CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)
      RTB(3)=ALAB(2)
      READ(5,3000)TITLE
      CALL DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)
      RTB(3)=ALAB(3)
      READ(5,3000)TITLE
      CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
 3000 FORMAT(6A8)
      STOP
      END
       SUBROUTINE RD(IUN,IO,IRS,IREC,IRQ)
C
C          THIS PROCEDURE FURNISHED BY DR. TIM STANTON,
C          DEPARTMENT OF OCEANOGRAPHY.
C
C               READ DATA FROM IUN, ALLIGN , CHECK & RETURN
C
C        IUN=TAPE NUMBER, EG 20
C        IO=INTEGER*2 ARRAY, 16 LONG,(VALUES 0-4095, SUBTRACT 2048)*5
C               /2028.  GIVES VOLTAGE
C        IRS= NUMBER OF RESINCS ALLOWED (ERRORS)
C        IREC= COUNTER OF RECORDS (FRAMES OF DATA)
C            BLOCK 512 BITS,   32 BITS = RECORD
C            800 BPI TAPE UNLABLED
C        IRQ= NUMBER OF ACTUAL RESINCS (ERRORS)
C
C
       INTEGER * 2 IO(16),IP(16)
       DATA IRR /0/
       IF (IREC.EQ.0) IS=0
```

```
      IER=0
20    FORMAT (16A2)
      IF (IS.NE.0) GO TC 50
      READ (IUN,20,END=900) IP
      IREC=IREC+1
40    IS=IS+1
      IF (IS.LT.17) GO TO 50
      READ (IUN,20,END=900) IP
     IS=1
     IREC=IREC+1
50   ICH=IMASK(IF(IS),3,0)+1
C     WRITE (6,55) ICH,IS,IUN,IREC
55    FORMAT ('  RESYNCING ICH,IS,IUN,IREC ',4I8)
C
     IF (ICH.NE.1) GO TO 40
     DC 100 I=1,16
      IO(I)=ISHIFT(IP(IS),4)
     ICH=IMASK(IP(IS),3,0)+1
     IF (ICH.EQ.I) GO TO 80
     IER=IER+1
     WRITE (6,70)  IUN,IREC ,I,ICH,IER
7C    FORMAT (' UNIT ',I3,' RECORD ',I6,'CHAN & DATA CH ',2I4,
    $ 'ERRORS ',I7)
80    IS=IS+1
      IF (IS.LT.17) GO TO 100
      READ (IUN,20,END=9CC) IP
      IS=1
      IREC=IREC+1
100   CONTINUE
C
      IF (IER.EC.0) GO TO 150
      IRR=IRR+1
      IF (IRR.LT.IRS) GC TO 120
      WRITE (6,110)
110   FORMAT ('1 STCPPED IN SUB RD BECAUSE OF IRR.GT.',I6,' AT L11C')
      IRQ=IRR
      STOP
120   CONTINUE
      WRITE (6,130) IREC,IRR
130   FORMAT (' RESYNC AT FRAME ',I6,' WITH TOTAL ERRORS ',I7)
      IER=0
      IRQ=IRR
      GO TO 50
150   CONTINUE
      RETURN
900   WRITE (6,910) IUN,IREC
910   FORMAT ('1   END OF UNIT ',I3,' AT REC ',I7)
      STOP
```

```
      END
      FUNCTION  ISHIFT (IN,NPLC)
C               RETURNS SHIFTED VALUE OF I*2 WORD IN
C               -VE LEFT,+VE RIGHT SHIFT
C
      INTEGER * 2 IN
      IP=IN
      IF (IP.LT.0) IP=IP+65536
      IF (NPLC.LT.0) GO TO 30
      ISHIFT=IP/(2**IABS(NPLC))
      RETURN
 30   ISHIFT=IP*(2**IABS(NPLC))
      IF (ISHIFT.GT.65535) ISHIFT=MOD(ISHIFT,65536)
      RETURN
      END
      FUNCTION  IMASK (IN,IBL,IBR)
C               MASK I*2 WORD IN OUTSIDE BITS IBL & IBR
C
      INTEGER * 2 IN,IO
      IO=IN
      IF (IBR.EQ.0) GO TO 50
      IT=ISHIFT(IN,IBR)
      IO=IT
 50   IP=ISHIFT(IO,IBL-15-IBR)
      IO=IP
      IMASK=ISHIFT(IO,15-IBL)
      RETURN
      END
/*
//GO.SYSIN DD *
CHEW'S RIDGE    ,  4 AUG 83, 1802-1819 LOCAL
X COIL AMP IN VOLTS
CHEW'S RIDGE    ,  4 AUG 83, 1802-1819 LOCAL
Y COIL AMP IN VOLTS
CHEW'S RIDGE    ,  4 AUG 83, 1802-1819 LOCAL
Z COIL AMP IN VOLTS
CHEW'S RIDGE    ,  4 AUG 83, 1802-1819 LOCAL
X COIL AMP IN VOLTS
CHEW'S RIDGE    ,  4 AUG 83, 1802-1819 LOCAL
Y COIL AMP IN VOLTS
CHEW'S RIDGE    ,  4 AUG 83, 1802-1819 LOCAL
Z COIL AMP IN VOLTS
/*
//GO.FT20F001 DD UNIT=3400-4,VOL=SER=CRDT3A,DISP=(OLD,KEEP),
//             LABEL=(1,NL,,IN),
//             DCB=(RECFM=FB,LRECL=32,BLKSIZE=512,DEN=2)
//GO.SYSDUMP DD SYSOUT=A
```

```
/*                                                                VOLO 2410
//                                                                VOLO 2420
```

APPENDIX D

VODIG COMPUTER PROGRAM

```
//CHFI23S JOB (2992,0165),'ANTHONY    SMC 2123',CLASS=G
//*MAIN ORG=NPGVM1.2992P,LINES=(75)
//*FORMAT PR,DDNAME=PLOT.SYSVECTR,DEST=LOCAL
// EXEC FRTXCLGP,PARM.LKED='LIST,MAP,XREF',REGION.GC=2048K
//FORT.SYSIN DD *
C        THIS PROGRAM READS IN DATA FROM DIGITAL TAPES USING THE
C     SUBROUTINE RD, NORMALIZES THE DATA BETWEEN -5 AND +5 VOLTS, APPLIES
C     A DIGITAL BANDPASS FILTER BETWEEN .04 AND .6 HZ DEVELOPED BY MIKE
C     HLETE AND THEN PUTS THE DATA THROUGH A 144 POINT DOUBLE RUNNING
C     AVERAGE SMOOTHING ROUTINE.
C
      INTEGER*2 IN(16)
C       ARRAY 'IN' IS USED IN READING DATA FROM TAPE
      REAL*8 XX(8196),YY(8196),ZZ(8196),XXS(8196),YYS(8196),ZZS(8196)
      REAL*8 FIX(18),FOX(18),FIY(18),FOY(18),FIZ(18),FOZ(18)
C       THE ABOVE REAL*8 ARRAYS ARE USED TO ORDER INPUT DATA AND
C       INITIALLY REPRESENT VOLTAGE - TIME SERIES INFORMATION.
      DIMENSION ZZX1(65568),ZZY1(65568),ZZV1(65568)
      DIMENSION TIME2(65568)
      DATA FIX,FIY/36*0./
      DATA FIZ/18*0./
      INTEGER K,C,I5,I4
      REAL SUMX,SUMY,SUMZ,SUMT,AVE1,AVE2,AVE3,AVE4
      INTEGER*4 ITB(12)/12*0/
      REAL*4    RTB(28)/28*0.0/
      REAL ALAB(4)/'CH-X','CH-Y','CH-Z','TOT'/
      REAL*8 TITLE(12)
      EQUIVALENCE(TITLE(1),RTB(5))
C       ARRAYS 'ITB','RTB','ALAB',AND 'TITLE' ARE USED IN GENERATING
C       THE VERTSATEC PLOTTER OUTPUT.
      DATA XX,YY/16392*0./
      DATA ZZ/8196*0./
      K=0
      I5=5
      I6=1
C    THE FOLLOWING LOOP ADVANCES THE DIGITAL TAPE BY ISEC SECONDS.
C
      ISEC=1940
      ITL=ISEC*64
      DO 55 JJ=1,ITL
      CALL RD(20,IN,200,IREC,IRR)
   55 CONTINUE
      IFRAME=8196
      NR=3
      FNR=FLOAT(NR)
      DO 70 L1=1,NR
C       THE DO LOOP ENDING WITH STATEMENT 70 ENABLES THE PROGRAM TO
C       PROCESS A LARGE AMOUNT OF DATA BY REPEATING THE PROCESS IN
```

```
C         BLOCKS.                                                       VODO0490
C         'NR' REPRESENTS THE NUMBER OF DATA SEQUENCES.                 VODO0500
C         1 SEQUENCE CURRENTLY EQUALS 8192 DATA POINTS FOR EACH CHANNEL VODO0510
C         OR 128 SECONDS OF DATA.                                       VODO0520
C                                                                       VODO0530
C          THE DO LOOP ENDING WITH 60 READS THE DATA FROM THE PCM FRAME VODO0540
C          STRIPS OUT THE SYNC CODE, AND SORTS OUT THE DATA BY COIL     VODO0550
C          CHANNEL                                                      VODO0560
        DO 60 JJ=5,IFRAME                                               VODO0570
        CALL RD(20,IN,1000,IREC,IRR)                                    VODO0580
     58 XX(JJ)=IN(2)                                                    VODO0590
        YY(JJ)=IN(3)                                                    VODO0600
        ZZ(JJ)=IN(4)                                                    VODO0610
     60 CONTINUE                                                        VODO0620
        N=8196                                                          VODO0630
        FN=FLOAT(N)                                                     VODO0640
        DELTAT=1./64.                                                   VODO0650
C       NORMALIZE THE DATA BETWEEN +5 AND -5 VOLTS.  FOR LAMESA DATA,   VODO0660
C       SUBTRACT 1.36, 1.0 AND 1.0 FROM XX, YY AND ZZ RESPECTIVELY, TO  VODO0670
C       REMOVE DC COMPONENT.                                            VODO0680
        DO 20 J=5,N                                                     VODO0690
        XX(J)=((XX(J)-2048.)*5./2048.)                                  VODO0700
        YY(J)=((YY(J)-2048.)*5./2048.)                                  VODO0710
        ZZ(J)=((ZZ(J)-2048.)*5./2048.)                                  VODO0720
C         'XX' IS THE X-COIL DATA, 'YY' IS THE Y-COIL DATA,             VODO0730
C         'ZZ' IS THE Z-COIL DATA                                       VODO0740
C          NORTH-SOUTH COMPONENT (XX) AND THE VERTICAL COMPONENT (ZZ)   VODO0750
     20 CONTINUE                                                        VODO0760
        DO 91 I3=5,8196                                                 VODO0770
        ZZX1(I5)=XX(I3)                                                 VODO0780
        ZZY1(I5)=YY(I3)                                                 VODO0790
        ZZV1(I5)=ZZ(I3)                                                 VODO0800
        I5=I5+1                                                         VODO0810
     91 CONTINUE                                                        VODO0820
     70 CONTINUE                                                        VODO0830
C       DOUBLE RUNNING POINT AVERAGE                                    VODO0840
        DO 73 L2=1,2                                                    VODO0850
        Q=0                                                             VODO0860
        DO 74 IS=5,65423                                                VODO0870
        SUMX=0.0                                                        VODO0880
        SUMY=0.0                                                        VODO0890
        SUMZ=0.0                                                        VODO0900
        DO 75 J=5,149                                                   VODO0910
        SUMX=ZZX1(Q+J)+SUMX                                             VODO0920
        SUMY=ZZY1(Q+J)+SUMY                                             VODO0930
        SUMZ=ZZV1(Q+J)+SUMZ                                             VODO0940
     75 CONTINUE                                                        VODO0950
        ZZX1(IS)=SUMX/144.                                              VODO0960
```

```
      ZZY1(IS)=SLMY/144.
      ZZV1(IS)=SLMZ/144.
      Q=Q+1
   74 CCNTINUE
   73 CCNTINUE
C     APPLY DIGITAL FILTER TO DATA BLOCK
      K2=5
      DC 92 M1=1,NR
      DC 100 K1=5,8196
      XX(K1)=ZZX1(K2)
      YY(K1)=ZZY1(K2)
      ZZ(K1)=ZZV1(K2)
      K2=K2+1
  100 CCNTINUE
      CALL DIGFIL(XX,FIX,XXS,FOX)
      CALL DIGFIL(YY,FIY,YYS,FOY)
      CALL DIGFIL(ZZ,FIZ,ZZS,FOZ)
      DC 21 L=1,18
      FIX(L)=FOX(L)
      FIY(L)=FOY(L)
      FIZ(L)=FOZ(L)
   21 CCNTINUE
      I4=1
      DC 90 I3=5,8196
      ZZX1(I6)=XXS(I3)
      ZZY1(I6)=YYS(I3)
      ZZV1(I6)=ZZS(I3)
      TIME2(I6)=(CELTAT*FLCAT(I4))+(128.0*FLOAT(K))
      I4=I4+1
      I6=I6+1
   90 CCNTINUE
      K=K+1
   92 CCNTINUE
      NL=8192*NR-1280
      DC 98 I7=1,NL
      ZZX1(I7)=ZZX1(I7+1280)
      ZZY1(I7)=ZZY1(I7+1280)
      ZZV1(I7)=ZZV1(I7+1280)
   98 CCNTINUE
C
C    VERSATEC PLCT OF V - TIME SERIES VOLTAGE SMCCTHEC
C
      NPTS=380./CELTAT +1.
C       'NPTS' DETERMINES NUMBER OF POINTS NECESSARY IN CRDER FCR
C        THE 0 TC NPTS  SECS RANGE TO BE PLOTTED.
C       FOR THE FCLLOWING 'ITB' AND 'RTB' VALUES REVIEW THE WRITE-UP
C       FOR THE SLBROUTINE PROCEDURE 'DRAWP'.
      ITB(3)=20
```

```
      ITB(4)=8
      ITB(7)=1
      ITB(12)=0
      RTB(1)=0.0
      RTB(2)=0.0
      RTB(3)=ALAE(1)
      READ(5,300C)TITLE
      CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)
      RTB(3)=ALAE(2)
      READ(5,3000)TITLE
      CALL DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)
      RTB(3)=ALAE(3)
      READ(5,3000)TITLE
      CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
      ITB(3)=7
      ITB(4)=5
      ITB(12)=0
      RTB(3)=ALAE(1)
      READ(5,300C)TITLE
      CALL DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)
      RTB(3)=ALAE(2)
      READ(5,300C)TITLE
      CALL DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)
      RTB(3)=ALAE(3)
      READ(5,300C)TITLE
      CALL DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
 3000 FCRMAT(6A8)
      STOP
      END
       SUBROUTINE RD(IUN,IC,IRS,IREC,IRQ)
C
C         THIS PRCCEDURE FURNISHED BY DR. TIM STANTCN,
C         DEPARTMENT OF CCEANOGRAPHY.
C
C              READ DATA FROM IUN, ALLIGN , CHECK & RETURN
C
C        IUN=TAPE NUMBER, EG 20
C        IO=INTEGER*2 ARRAY, 16 LONG,(VALUES 0-4095, SUBTRACT 2048)*5
C             /2028.  GIVES VOLTAGE
C        IRS= NUMEER OF RESINCS ALLOWED (ERRORS)
C        IREC= COUNTER OF RECORDS (FRAMES CF DATA)
C            BLOCK 512 BITS,   32 BITS = RECORD
C            800 BPI TAPE UNLABLED
C        IRQ= NUMBER OF ACTUAL RESINCS (ERRORS)
C
C
       INTEGER * 2 IO(16),IP(16)
       CATA IRR /C/
```

```
      IF (IREC.EC.0) IS=0
      IER=0
20    FORMAT (16A2)
      IF (IS.NE.0) GO TO 50
      READ (IUN,20,END=90C) IP
      IREC=IREC+1
40    IS=IS+1
      IF (IS.LT.17) GO TO 50
      READ (IUN,20,END=900) IP
     IS=1
     IREC=IREC+1
50   ICH=IMASK(IP(IS),3,0)+1
C     WRITE (6,55) ICH,IS,IUN,IREC
55    FORMAT ('  RESYNCING ICH,IS,IUN,IREC ',4I8)
C
     IF (ICH.NE.1) GO TO 40
     DC 100 I=1,16
      IO(I)=ISHIFT(IP(IS),4)
     ICH=IMASK(IP(IS),3,0)+1
     IF (ICH.EQ.1) GO TO 80
     IER=IER+1
     WRITE (6,7C)  IUN,IREC ,I,ICH,IER
7C    FORMAT (' UNIT ',I3,' RECORD ',I6,'CHAN & DATA CH ',2I4,
    $ 'ERRORS ',I7)
80    IS=IS+1
      IF (IS.LT.17) GO TO 100
      READ (IUN,20,END=9CC) IP
      IS=1
      IREC=IREC+1
100   CONTINUE
C
      IF (IER.EC.0) GO TO 150
      IRR=IRR+1
      IF (IRR.LT.IRS) GO TO 120
      WRITE (6,110)
110   FORMAT ('1 STCPPED IN SUB RD BECAUSE OF IRR.GT.',I6,' AT L11C')
      IRQ=IRR
      STOP
120   CONTINUE
      WRITE (6,130) IREC,IRR
130   FORMAT (' RESYNC AT FRAME ',I6,' WITH TOTAL ERRORS ',I7)
      IER=0
      IRQ=IRR
      GO TO 50
150   CONTINUE
      RETURN
900   WRITE (6,910) IUN,IREC
910   FORMAT ('1   END OF UNIT ',I3,' AT REC ',I7)
```

```
      STOP
      END
C
      SUBROUTINE DIGFIL(INFLD,FILE,SIG,FOLE)
C      THE ABOVE REAL*4 ARRAYS ARE USED TO ORDER INPUT DATA AND
C      INITIALLY REPRESENT VOLTAGE - TIME SERIES INFORMATION.
      REAL*8 INFLD(8196),OUTFLD(8196),SIG(8196)
      REAL*8 YO(8196),YPO(8196),FILE(18),FOLE(18)
      REAL*8 XI(8196),XII(8196),XIII(8196),XIV(8196),XV(8196)
      DATA XI,XII/16392*0./
      DATA XIII,XIV/16392*0./
      DATA XV,YO/16392*0./
      DATA YPO/8196*0./
      DATA OUTFLD/8196*0./
      INTEGER K9
C
C     THE COMPLEX*8 ARRAYS ARE USED TO ORDER INPUT DATA AND REPRESENT
C     VOLTAGE-TIME SERIES INFORMATION.
C
      REAL*8 T,AFHP1,AFHP2,BFHP0,BFHP1,BFHP2,A,B,C,D,E,F,A1
      REAL*8 B1,C1,D1,E1,F1,G1,H1,I1,J1,K1,L1
      REAL*8 AA,BB,CC,DD,EE,FF,AA1,BB1,CC1,DD1,EE1,FF1,GG1,HH1,II1
      REAL*8 JJ1,KK1,LL1
      REAL*8 ASHP41,ASHP42,ASHP43,ASHP44,ASHP45,ASHP46,ASHP47
      REAL*8 ASLP61,ASLP62,ASLP63,ASLP64
      REAL*8 BSLP60,BSLP61,BSLP62,BSLP63,BSLP64
C
C     DEFINE AND COMPUTE ALL COEFFICIENTS
C
      T=1./64.
C
C     COEFFICIENTS FOR FIXED HIGH PASS FILTER
C
      AFHP1=-((T**2/160.-2.)/(1.+T/8.+T**2/320.))
      AFHP2=-((1.-T/8.+T**2/320.)/(1.+T/8.+T**2/320.))
      BFHP0=(1./(1.+T/8.+T**2/320.))
      BFHP1=-(2./(1.+T/8.+T**2/320.))
      BFHP2=(1./(1.+T/8.+T**2/320.))
C
C     COEFFICIENTS FOR SELECTIVE HIGH PASS FILTER
C     IN THIS CASE,    FREQ(LOWER)=0.04 HZ
C
      A=12.52096/40.82834
      B=1./40.82834
      C=11.00999/45.28317
      D=1./45.28317
      E=7.41498/57.57668
      F=1./57.57668
```

```
      A1=1.+A*T/2.+B*(T**2)/4.
      B1=-2.+B*(T**2/2.)
      C1=1.-A*T/2.+B*(T**2)/4.
      D1=1.+C*T/2.+D*(T**2)/4.
      E1=-2.+D*(T**2)/2.
      F1=1.-C*T/2.+D*(T**2)/4.
      G1=1.+E*T/2.+F*(T**2)/4.
      H1=-2.+F*(T**2)/2.
      I1=1.-E*T/2.+F*(T**2)/4.
C
C     CODE IS "ASHP41" MEANS "A1 COEFFICIENT FOR THE SELECTABLE HIGH
C     PASS FILTER WITH LOWER LIMIT 0.04 HZ"
C
      ASHP41=1./(A1*D1*G1)
      ASHP42=-(C1/A1)
      ASHP43=-(B1/A1)
      ASHP44=-(E1/D1)
      ASHP45=-(F1/D1)
      ASHP46=-(H1/G1)
      ASHP47=-(I1/G1)
C
C     COEFFICIENTS FOR SELECTABLE LOW PASS FILTER WITH UPPER FREQ
C     OF 0.6 HZ
C
      A=1./0.03492
      B=0.35804/0.03492
      C=1./0.03492
      D=1./0.02779
      E=0.20696/0.02779
      F=1./0.02779
      A1=A*(T**2)/4.
      B1=2.*A1
      C1=A1
      D1=D*(T**2)/4.
      E1=2.*D1
      F1=D1
      G1=(1.+B*T/2.+C*(T**2)/4.)
      H1=(-2.+C*(T**2)/2.)
      I1=(1.-B*T/2.+C*(T**2)/4.)
      J1=(1.+E*T/2.+F*(T**2)/4.)
      K1=(-2.+F*(T**2)/2.)
      L1=(1.-E*T/2.+F*(T**2)/4.)
      ASLP61=-(G1*K1+H1*J1)/(G1*J1)
      ASLP62=-(G1*L1+H1*K1+I1*J1)/(G1*J1)
      ASLP63=-(H1*L1+I1*K1)/(G1*J1)
      ASLP64=-(I1*L1)/(G1*J1)
      BSLP60=(A1*D1)/(G1*J1)
      BSLP61=(A1*E1+B1*D1)/(G1*J1)
```

```
      BSLP62=(A1*F1+B1*E1+C1*D1)/(G1*J1)
      BSLP63=(B1*F1+C1*E1)/(G1*J1)
      BSLP64=(C1*F1)/(G1*J1)
C
C     SET TRANSFERED VALUES EQUAL TC INTIIAL ARRAY VALUES AND
C     APPLY DIGITAL FILTER TO ARRAY INFLD
      YC(4)=FILE(1)
      YO(3)=FILE(2)
      XI(4)=FILE(3)
      XI(3)=FILE(4)
      XIII(4)=FILE(5)
      XIII(3)=FILE(6)
      XV(4)=FILE(7)
      XV(3)=FILE(8)
      YPO(4)=FILE(9)
      YPO(3)=FILE(10)
      YPO(2)=FILE(11)
      YFO(1)=FILE(12)
      CUTFLD(4)=FILE(13)
      CUTFLD(3)=FILE(14)
      CLTFLD(2)=FILE(15)
      OLTFLD(1)=FILE(16)
      INFLD(4)=FILE(17)
      INFLD(3)=FILE(18)
      N=8196
      DC 92 I=5,N
      I1=I-1
      I2=I-2
      I3=I-3
      I4=I-4
      YC(I)=BFHPC*INFLD(I)+BFHP1*INFLD(I1)+BFHP2*INFLC(I2)+AFHP1*YO(I1)
     $+AFHP2*YO(I2)
      XI(I)=ASHP41*YO(I)+ASHP42*XI(I2)+ASHP43*XI(I1)
      XII(I)=XI(I)+XI(I2)-2.*XI(I1)
      XIII(I)=XII(I)+ASHP44*XIII(I1)+ASHP45*XIII(I2)
      XIV(I)=XIII(I)-2.*XIII(I1)+XIII(I2)
      XV(I)=XIV(I)+ASHP46*XV(I1)+ASHP47*XV(I2)
      YPO(I)=XV(I)+XV(I2)-2.*XV(I1)
      GP1=ASLP61*OUTFLD(I1)+ASLP62*OUTFLD(I2)+ASLP63*CUTFLD(I3)+ASLP64
     $*CUTFLC(I4)
      GP2=BSLP60*YPO(I)+BSLP61*YPO(I1)+BSLP62*YPC(I2)+BSLF63*YPO(I3)
     $+BSLP64*YPC(I4)
      CLTFLD(I)=GP1+GP2
      SIG(I)=OUTFLD(I)
C     WRITE(6,1) INFLD(I),YO(I),XI(I),XII(I),XIII(I),XIV(I)
C   1 FCRMAT(' A',6G10.5)
C     WRITE(6,2) XV(I),YPO(I),GP1,GP2,OUTFLD(I),SIG(I)
C   2 FORMAT(' B',6G10.5)
```

```
   92 CCNTINUE
      FCLE(1)=YO(8196)
      FCLE(2)=YO(8195)
      FCLE(3)=XI(8196)
      FCLE(4)=XI(8195)
      FOLE(5)=XIII(8196)
      FCLE(6)=XIII(8195)
      FCLE(7)=XV(8196)
      FCLE(8)=XV(8195)
      FCLE(9)=YPC(8196)
      FOLE(10)=YPC(8195)
      FCLE(11)=YPC(8194)
      FCLE(12)=YPC(8193)
      FCLE(13)=OLTFLD(8196)
      FCLE(14)=OLTFLD(8195)
      FCLE(15)=OLTFLD(8194)
      FCLE(16)=OLTFLD(8193)
      FCLE(17)=INFLD(8196)
      FCLE(18)=INFLD(8195)
      RETURN
      END
      FUNCTION ISHIFT (IN,NPLC)
C               RETURNS SHIFTED VALUE OF I*2 WORD IN
C               -VE LEFT,+VE RIGHT SHIFT
C
      INTEGER * 2 IN
      IP=IN
      IF (IP.LT.C) IP=IP+65536
      IF (NPLC.LT.0) GC TC 30
      ISHIFT=IP/(2**IABS(NPLC))
      RETURN
   30 ISHIFT=IP*(2**IABS(NPLC))
      IF (ISHIFT.GT.65535) ISHIFT=MOD(ISHIFT,65536)
      RETURN
      END
      FUNCTION IMASK (IN,IBL,IBR)
C               MASK I*2 WCRD IN OUTSIDE BITS IBL & IBR
C
      INTEGER * 2 IN,IO
      IO=IN
      IF (IBR.EC.0) GO TC 50
      IT=ISHIFT(IN,IBR)
      IO=IT
   50 IP=ISHIFT(IO,IBL-15-IBR)
      IO=IP
      IMASK=ISHIFT(IO,15-IBL)
      RETURN
      END
```

```
/*
//GO.SYSIN DD *
CHEW'S RIDGE    , 4 AUG 83, 1834-1840 LOCAL
X COIL AMP IN VOLTS
CHEW'S RIDGE    , 4 AUG 83, 1834-1840 LOCAL
Y COIL AMP IN VOLTS
CHEW'S RIDGE    , 4 AUG 83, 1834-1840 LOCAL
Z COIL AMP IN VOLTS
CHEW'S RIDGE    , 4 AUG 83, 1834-1840 LOCAL
X COIL AMP IN VOLTS
CHEW'S RIDGE    , 4 AUG 83, 1834-1840 LOCAL
Y COIL AMP IN VOLTS
CHEW'S RIDGE    , 4 AUG 83, 1834-1840 LOCAL
Z COIL AMP IN VOLTS
/*
//GO.FT20F001 DD UNIT=3400-4,VOL=SER=CRDT3A,DISP=(OLD,KEEP),
//             LABEL=(1,NL,,IN),
//             DCB=(RECFM=FB,LRECL=32,BLKSIZE=512,DEN=2)
//GO.SYSDUMP DD SYSOUT=A
/*
//
```

APPENDIX E

MASS STORAGE COMPUTER PROGRAM

```
//TAPEMS5 JOB (2992,0165),'ANTHONY SMC 2123',CLASS=G                   JOE00010
//*MAIN ORG=NPGVM1.2992P                                                JOE00020
// EXEC FORTXCLG                                                        JOE00030
//FORT.SYSIN DD *                                                       JOE00040
C                                                                       JOE00050
C     THIS PROGRAM READS DATA FROM A COMPUTER TAPE, NORMALIZES THE DATA JOE00060
C     BETWEEN +5 AND -5 VOLTS AND STORES IT IN THE IBM 3033 MASS STORAGE JOE00070
C     SYSTEM FOR FUTURE RECALL. THE DATA IS READ AND TRANSFERRED IN     JOE00080
C     BLOCKS OF 8192 SAMPLES (128 SECONDS OF DATA IN EACH BLOCK).       JOE00090
C           THE ARRAY 'IN' WILL BE USED TO                              JOE00100
C           RECEIVE THE DATA PASSED FROM                                JOE00110
C           THE SUBROUTINE 'RD' AND THEN                                JOE00120
C           TRANSFERRED TO THE APPROPRIATE                              JOE00130
C           XXX OR YYY OR ZZZ ARRAY.                                    JOE00140
      INTEGER*2 IN(16)                                                  JOE00150
      COMPLEX*8 XXX(8192),YYY(8192),ZZZ(8192)                           JOE00160
      DATA XXX,YYY/16384*(0.0,0.0)/                                     JOE00170
      DATA ZZZ/8192*(0.,0.)/                                            JOE00180
C           THE FOLLOWING SECTION READS THE FIRST                       JOE00190
C           ISEC SECONDS OF DATA FROM THE TAPE                          JOE00200
C           AND DISCARDS THIS DATA.                                     JOE00210
C                                                                       JOE00220
      ISEC=200                                                          JOE00230
      ITL=ISEC*64                                                       JOE00240
      DO 55 JJ=1,ITL                                                    JOE00250
      CALL RD(20,IN,200,IREC,IRR)                                       JOE00260
   55 CONTINUE                                                          JOE00270
      IFRAME=8192                                                       JOE00280
C      THE VARIABLE NR SPECIFIES THE NUMBER OF BLOCKS OF DATA TO BE     JOE00290
C      READ FROM THE TAPE AND STORED IN THE MSS.                        JOE00300
      NR=19                                                             JOE00310
      DO 70 L1=1,NR                                                     JOE00320
C                                                                       JOE00330
C           THE NEXT LOOP READS NR FRAMES OF DATA (EACH FRAME           JOE00340
C           128 SECS LONG AT 64 HZ SAMPLING RATE) USING THE             JOE00350
C           SUBROUTINE RD, PROVIDED BY DR. TIM STANTON OF THE           JOE00360
C           NAVAL POSTGRADUATE SCHOOL.                                  JOE00370
C                                                                       JOE00380
      DO 60 JJ=1,IFRAME                                                 JOE00390
      CALL RD(20,IN,1000,IREC,IRR)                                      JOE00400
      XXX(JJ)=IN(2)                                                     JOE00410
      YYY(JJ)=IN(3)                                                     JOE00420
      ZZZ(JJ)=IN(4)                                                     JOE00430
   60 CONTINUE                                                          JOE00440
      N=8192                                                            JOE00450
      DO 20 J=1,N                                                       JOE00460
C                                                                       JOE00470
C           THE NEXT 4 STEPS CONVERT THE                                JOE00480
```

```
C          DATA TC VOLTAGE BETWEEN +5 AND -5 VOLTS ANC SETS TFE
C          IPAGINARY PART OF THE COMPLEX NUMBER EQUAL TO ZERO.
C
      XXX(J)=((XXX(J)-2C48.)*5./2048.)-1.36
C     XXX(J)=REAL(XXX(J))
      YYY(J)=((YYY(J)-2C48.)*5./2048.)-1.0
C     YYY(J)=REAL(YYY(J))
      ZZZ(J)=((ZZZ(J)-2048.)*5./2048.)-1.0
C     ZZZ(J)=REAL(ZZZ(J))
   20 CCNTINUE
C
C
C          TFE NEXT WRITE STATEMENTS SEND
C          THE CCNVERTED DATA TO MSS
C          FOR FLTURE MANIPULATION AND RECALL.
C
C
C
C
      WRITE(21) XXX
C     WRITE(6,*) XXX(1),XXX(8192)
      WRITE(21) YYY
C     WRITE(6,*) YYY(1),YYY(8192)
      WRITE(21) ZZZ
C     WRITE(6,*) ZZZ(1),ZZZ(8192)
   70 CONTINUE
      WRITE(6,71)
   71 FORMAT(' FINISHED WRITING TO MASS STORAGE')
      ENDFILE 21
      STOP
      END
       SUBROUTINE RD(IUN,IC,IRS,IREC,IRQ)
C
C         THIS PRCCEDURE FURNISHED BY DR. TIM STANTCN,
C         DEPARTMENT OF OCEANOGRAPHY.
C
C              READ DATA FROM IUN, ALLIGN , CHECK & RETURN
C
C       IUN=TAPE NUMBER, EG 20
C       IO=INTEGER*2 ARRAY, 16 LONG,(VALUES 0-4095, SLBTRACT 2048)*5
C              /2028.  GIVES VOLTAGE
C       IRS= NUMBER OF RESINCS ALLOWED (ERRORS)
C       IREC= COLNTER OF RECORDS (FRAMES CF DATA)
C           BLOCK 512 BITS,   32 BITS = RECORC
C           800 BPI TAPE LNLABLED
C       IRQ= NUMEER OF ACTUAL RESINCS (ERRORS)
C
C
```

```
      INTEGER * 2 IO(16),IP(16)
      CATA IRR /C/
      IF (IREC.EQ.0) IS=0
      IER=0
 20   FORMAT (16A2)
      IF (IS.NE.0) GO TO 50
      READ (IUN,20,END=900) IP
      IREC=IREC+1
 40   IS=IS+1
      IF (IS.LT.17) GO TC 50
      READ (IUN,20,END=9CC) IP
     IS=1
     IREC=IREC+1
 50  ICH=IMASK(IP(IS),3,0)+1
C     WRITE (6,55) ICH,IS,IUN,IREC
 55   FORMAT ('  RESYNCING ICH,IS,IUN,IREC ',4I8)
C
     IF (ICH.NE.1) GO TO 40
     DO 100 I=1,16
      IO(I)=ISHIFT(IP(IS),4)
     ICH=IMASK(IP(IS),3,0)+1
     IF (ICH.EQ.I) GO TO 80
     IER=IER+1
     WRITE (6,7C)  IUN,IREC ,I,ICH,IER
 70   FORMAT (' UNIT ',I3,' RECORD ',I6,'CHAN & DATA CH ',2I4,
    $ 'ERRORS ',I7)
 80   IS=IS+1
      IF (IS.LT.17) GO TO 100
      READ (IUN,20,END=900) IP
      IS=1
      IREC=IREC+1
 100  CONTINUE
C
      IF (IER.EC.0) GO TO 150
      IRR=IRR+1
      IF (IRR.LT.IRS) GO TO 120
      WRITE (6,110)
 110  FORMAT ('1 STOPPED IN SUB RD BECAUSE OF IRR.GT.',I6,' AT L110')
      IRQ=IRR
      STOP
 120  CONTINUE
      WRITE (6,130) IREC,IRR
 130  FORMAT (' RESYNC AT FRAME ',I6,' WITH TCTAL ERRORS ',I7)
      IER=0
      IRQ=IRR
      GO TO 50
 150  CCNTINUE
      RETURN
```

```
 900    WRITE (6,910) IUN,IREC                                                  JOE01450
 910    FORMAT ('1   END OF UNIT ',I3,' AT REC ',I7)                            JOE01460
        STOP                                                                    JOE01470
        END                                                                     JOE01480
                                                                                JOE01490
        FUNCTION ISHIFT (IN,NPLC)                                               JOE01500
C                RETURNS SHIFTED VALUE OF I*2 WORD IN                           JOE01510
C                -VE LEFT,+VE RIGHT SHIFT                                       JOE01520
C                                                                               JOE01530
        INTEGER * 2 IN                                                          JOE01540
        IP=IN                                                                   JOE01550
        IF (IP.LT.0) IP=IP+65536                                                JOE01560
        IF (NPLC.LT.0) GO TO 30                                                 JOE01570
        ISHIFT=IP/(2**IABS(NPLC))                                               JOE01580
        RETURN                                                                  JOE01590
 30     ISHIFT=IP*(2**IABS(NPLC))                                               JOE01600
        IF (ISHIFT.GT.65535) ISHIFT=MOD(ISHIFT,65536)                           JOE01610
        RETURN                                                                  JOE01620
        END                                                                     JOE01630
        FUNCTION IMASK (IN,IBL,IBR)                                             JOE01640
C                MASK I*2 WORD IN OUTSIDE BITS IBL & IBR                        JOE01650
C                                                                               JOE01660
        INTEGER * 2 IN,IO                                                       JOE01670
        IO=IN                                                                   JOE01680
        IF (IBR.EQ.0) GO TO 50                                                  JOE01690
        IT=ISHIFT(IN,IBR)                                                       JOE01700
        IO=IT                                                                   JOE01710
 50     IP=ISHIFT(IO,IBL-15-IBR)                                                JOE01720
        IO=IP                                                                   JOE01730
        IMASK=ISHIFT(IO,15-IBL)                                                 JOE01740
        RETURN                                                                  JOE01750
        END                                                                     JOE01760
/*                                                                              JOE01770
//GO.FT21F001 DD UNIT=3330V,MSVGP=PUB4A,DISP=(NEW,CATLG),                       JOE01780
//               DSN=MSS.S2992.LMDT3D,                                          JOE01790
//               DCB=(RECFM=VBS,BLKSIZE=4096,LRECL=4092),                       JOE01800
//               SPACE=(CYL,(8,4))                                              JOE01810
//GO.FT20F001 DD UNIT=3400-4,VOL=SER=LMDT3,DISP=(OLD,PASS),                     JOE01820
//               LABEL=(1,NL,,IN),                                              JOE01830
//               DCB=(RECFM=FB,LRECL=32,BLKSIZE=512,DEN=2)                      JOE01840
//                                                                              JOE01850
```

APPENDIX F

MAGFLD COMPUTER PROGRAM

```
//LAMA2CB JOB (1C29,0129),'STEVENS   SMC 2670',CLASS=G
//*MAIN ORG=NPGVM1.1029P,LINES=(65)
//*FORMAT PR,DDNAME=PLOT.SYSVECTR,DEST=LOCAL
// EXEC FRTXCLGP,PARM.LKED='LIST,MAP,XREF',REGION.GO=2048K
//FORT.SYSIN DD DSN=MSS.SYS3.NONIMSL.SOURCE(FOURT),DISP=SHR
//   DD *
      INTEGER*2 IN(16)
C       ARRAY 'IN' IS USED IN READING DATA FROM TAPE
      COMPLEX*8 XX(8192),YY(8192),ZZ(8192),TF(8192)
C       THE ABOVE COMPLEX*8 ARRAYS ARE USED TO ORDER INPUT DATA AND
C       INITIALLY REPRESENT VOLTAGE - TIME SERIES INFORMATION.
      DIMENSION TIME(8192),FREQ(8192),WORK(16384),FRQ2(8192)
      DIMENSION ZX1(8192),ZY1(8192),ZV1(8192),ZT1(8192)
      DIMENSION ZZX1(65536),ZZY1(65536),ZZV1(65536)
      DIMENSION ZZT1(65536),TIME2(65536)
C       THE 'Z' ARRAYS REPRESENT FREQUENCY DOMAIN (FF TRANSFORMED)
C       MAGNITUDE DATA AND ARE EVENTUALLY CONVERTED TO POWER SPECTRAL
C       DENSITY INFORMATION. ZX1,ZY1,ZV1,AND ZT1 REPRESENT MAGNITUDE
C       VALUES.
      INTEGER K,I4,I5,Q
      REAL SUMX,SUMY,SUMZ,SUMT,AVE1,AVE2,AVE3,AVE4
      REAL CONSTX,CONSTY,CONSTZ,CONSTT
      INTEGER*4 IIB(12)/12*0/
      REAL*4    RTB(28)/28*0.0/
      REAL ALAB(4)/'CH-X','CH-Y','CH-Z','TOT'/
      REAL*8 TITLE(12)
      EQUIVALENCE(TITLE(1),RTB(5))
C       ARRAYS 'ITE','RTB','ALAB',AND 'TITLE' ARE USED IN GENERATING
C       THE VERTSATEC PLOTTER OUTPUT.
      DATA XX,YY/16384*(0.,0.)/
      DATA ZZ,TF/16384*(0.,0.)/
      DATA ZX1,ZY1/16384*0./
      DATA ZV1,ZT1/16384*0./
      DATA TIME,FREQ/16384*0./
      K=0
      I4=1
      I5=1
      CONSTX=0.0
      CONSTY=0.0
      CONSTZ=0.0
      CONSTT=0.0
      SUMX=0.0
      SUMY=0.0
      SUMZ=0.0
      SUMT=0.0
      AVE1=0.0
      AVE2=0.0
      AVE3=0.0
```

```
      AVE4=0.0                                                          LFV00490
      DO 31 IN1=1,65536                                                 LFV00500
      ZZX1(IN1)=C.0                                                     LFV00510
      ZZY1(IN1)=0.0                                                     LFV00520
      ZZV1(IN1)=C.0                                                     LFV00530
      ZZT1(IN1)=0.0                                                     LFV00540
      TIME2(IN1)=C.0                                                    LFV00550
   31 CCNTINUE                                                          LFV00560
C        THE NEXT FIVE LINES SERVE AS A TIME DELAY IN STARTING THE      LFV00570
C        DATA ANALYSIS                                                  LFV00580
      ISEC=10                                                           LFV00590
      ITL=ISEC*64                                                       LFV00600
      DO 55 JJ=1,ITL                                                    LFV00610
      CALL RD(20,IN,200,IREC,IRR)                                       LFV00620
   55 CCNTINUE                                                          LFV00630
      IFRAME=8192                                                       LFV00640
      NR=8                                                              LFV00650
      FNR=FLCAT(NR)                                                     LFV00660
      DO 70 L1=1,NR                                                     LFV00670
C       THE DO LOCP ENDING WITH STATEMENT 70 ENABLES THE PROGRAM TO     LFV00680
C       PROCESS A LARGE AMOUNT OF DATA BY REPEATING THE PRCCESS IN      LFV00690
C       BLOCKS.                                                         LFV00700
C       'NR' REPRESENTS THE NUMBER OF DATA SEQUENCES TO BE AVERAGED.    LFV00710
C       1 SEQUENCE CURRENTLY EQUALS 8192 DATA POINTS FOR EACH CHANNEL   LFV00720
C       OR 256 SECCNDS OF DATA.                                         LFV00730
C                                                                       LFV00740
C        THE DO LOOP ENDING WITH 60 READS THE DATA FROM THE PCM FRAME   LFV00750
C        STRIPS OUT THE SYNC CODE, AND SORTS OUT THE DATA BY COIL       LFV00760
C        CHANNEL                                                        LFV00770
      DO 60 JJ=1,IFRAME                                                 LFV00780
      CALL RD(20,IN,1000,IREC,IRR)                                      LFV00790
      XX(JJ)=IN(2)                                                      LFV00800
      YY(JJ)=IN(3)                                                      LFV00810
      ZZ(JJ)=IN(4)                                                      LFV00820
   60 CCNTINUE                                                          LFV00830
C        THE FOLLCWING SECTION GENERATES THE TIME AND FREQUENCY         LFV00840
C        ARRAYS AND NORMALIZES THE INPUT PCM DATA TC VCLTAGE FORM       LFV00850
C        IN PREPARATION FOR FAST FOURIER TRANSFORM TC THE FREQUENCY     LFV00860
C        DOMAIN.                                                        LFV00870
      N=8192                                                            LFV00880
      FN=FLOAT(N)                                                       LFV00890
      DELTAT=1./64.                                                     LFV00900
      DELTAF=1./(FN*DELTAT)                                             LFV00910
      DO 20 J=1,N                                                       LFV00920
      TIME(J)=DELTAT*FLCAT(J)                                           LFV00930
      FREQ(J)=DELTAF*FLCAT(J)                                           LFV00940
      XX(J)=((XX(J)-2048.)*5./2048.)-1.36                               LFV00950
      XX(J)=REAL(XX(J))                                                 LFV00960
```

```
      YY(J)=((YY(J)-2048.)*5./2048.)-1.0
      YY(J)=REAL(YY(J))
      ZZ(J)=((ZZ(J)-2048.)*5./2048.)-1.0
      ZZ(J)=REAL(ZZ(J))
C        'XX' IS THE X-COIL DATA, 'YY' IS THE Y-COIL DATA,
C        'ZZ' IS THE Z-COIL DATA, AND 'TF' IS THE PROJECTION OF THE
C        NORTH-SOUTH COMPONENT (XX) AND THE VERTICAL COMPONENT (ZZ)
C        ON THE TOTAL GEOMAGNETIC FIELD VECTOR.
   20 CONTINUE
      DO 21 J=1,N
      FRQ2(J)=ALOG10(FREQ(J))
   21 CONTINUE
C        THE NEXT FOUR STATEMENTS PERFORM AN FFT ON THE INPUT
C        TIME SERIES DATA. SEE THE WRITEUP ON 'FOURT' FOR
C        FURTHER INFORMATION.
      CALL FOURT(XX,N,1,-1,0,WORK)
      CALL FOURT(YY,N,1,-1,0,WORK)
      CALL FOURT(ZZ,N,1,-1,0,WORK)
C       THE NEXT BLOCK OF STATEMENTS APPLY THE SYSTEM (VOLTAGE TO
C       B-FIELD) TRANSFER FUNCTION TO THE TRANSFORMED FREQUENCY
C       DOMAIN DATA.  THIS BLOCK ENDS AT STATEMENT 9.
C       THE TRANSFER FUNCTION CONVERTS VOLTS TO NANOTESLAS (GAMMAS).
C       ***WARNING*** THIS TRANSFER FUNCTIONS YIELDS AN INACCURATE
C       PHASE.  USE A DIFFERENT TRANSFER FUNCTION IF PHASE INFORMATION
C       NEEDED.
      DO 9 L=1,N
      FRQ=FREQ(L)
      IF(FRQ.LE.25.)GO TO 1
      XX(L)=XX(L)/28.
      GO TO 8
    1 IF(FRQ.LE.15.)GO TO 2
      XX(L)=XX(L)/(105.5-3.14*FRQ)
      YY(L)=YY(L)/(181.32-7.588*FRQ)
      ZZ(L)=ZZ(L)/(177.26-7.484*FRQ)
      GO TO 8
    2 IF(FRQ.LE.10.)GO TO 3
      XX(L)=XX(L)/(5.958*FRQ-30.97)
      YY(L)=YY(L)/(7.166*FRQ-39.99)
      ZZ(L)=ZZ(L)/(6.49*FRQ-32.35)
      GO TO 8
    3 IF(FRQ.LE.7.5)GO TO 4
      XX(L)=XX(L)/(3.492*FRQ-6.31)
      YY(L)=YY(L)/(4.252*FRQ-10.85)
      ZZ(L)=ZZ(L)/(4.044*FRQ-7.89)
      GO TO 8
    4 IF(FRQ.LE.5.)GO TO 5
      XX(L)=XX(L)/(2.6311*FRQ+0.14667)
      YY(L)=YY(L)/(3.012*FRQ-1.55)
```

```
      ZZ(L)=ZZ(L)/(3.184*FRQ-1.44)                                      LFV01450
      GC TO 8                                                           LFV01460
    5 IF(FRQ.LE.3.)GO TC 6                                              LFV01470
      XX(L)=XX(L)/(2.6311*FRQ+0.14667)                                  LFV01480
    7 YY(L)=YY(L)/(2.702*FRQ)                                           LFV01490
      ZZ(L)=ZZ(L)/(2.92*FRQ)                                            LFV01500
      GC TO 8                                                           LFV01510
    6 XX(L)=XX(L)/(2.72*FRQ)                                            LFV01520
      GC TO 7                                                           LFV01530
    8 CCNTINUE                                                          LFV01540
      TF(L)=(XX(L)*.5 + ZZ(L)*.866)                                     LFV01550
    9 CCNTINUE                                                          LFV01560
      CALL  FCURT(XX,N,1,1,1,WORK)                                      LFV01570
      CALL  FCURT(YY,N,1,1,1,WORK)                                      LFV01580
      CALL  FCURT(ZZ,N,1,1,1,WORK)                                      LFV01590
      CALL  FCURT(TF,N,1,1,1,WORK)                                      LFV01600
      DO 57 J=1,N                                                       LFV01610
      XX(J)=XX(J)/FN                                                    LFV01620
      YY(J)=YY(J)/FN                                                    LFV01630
      ZZ(J)=ZZ(J)/FN                                                    LFV01640
      TF(J)=TF(J)/FN                                                    LFV01650
   57 CCNTINUE                                                          LFV01660
      DC 56 I3=1,N                                                      LFV01670
      ZX1(I3)=CABS(XX(I3))                                              LFV01680
      ZY1(I3)=CABS(YY(I3))                                              LFV01690
      ZV1(I3)=CABS(ZZ(I3))                                              LFV01700
      ZT1(I3)=CABS(TF(I3))                                              LFV01710
   56 CCNTINUE                                                          LFV01720
C     THE NEXT 44 LINES OF CODE CORRECT DATA BLOCK END JUMPS.           LFV01730
      IF(K.NE.0) GO TO 36                                               LFV01740
      DO 66 IS=8048,8192                                                LFV01750
      SUMX=ZX1(IS)+SUMX                                                 LFV01760
      SUMY=ZY1(IS)+SUMY                                                 LFV01770
      SUMZ=ZV1(IS)+SUMZ                                                 LFV01780
      SUMT=ZT1(IS)+SUMT                                                 LFV01790
   66 CCNTINUE                                                          LFV01800
      CCNSTX=SUMX/144.                                                  LFV01810
      CCNSTY=SUMY/144.                                                  LFV01820
      CCNSTZ=SUMZ/144.                                                  LFV01830
      CCNSTT=SUMT/144.                                                  LFV01840
      DC 67 IS=1,8192                                                   LFV01850
      ZZX1(I4)=ZX1(IS)                                                  LFV01860
      ZZY1(I4)=ZY1(IS)                                                  LFV01870
      ZZV1(I4)=ZV1(IS)                                                  LFV01880
      ZZT1(I4)=ZT1(IS)                                                  LFV01890
      I4=I4+1                                                           LFV01900
   67 CCNTINUE                                                          LFV01910
      GC TO 37                                                          LFV01920
```

```
36 CCNTINLE
   SUMX=0.0
   SUMY=0.0
   SUMZ=0.0
   SUMT=0.0
   DC 68 IS=1,144
   SLMX=ZX1(IS)+SUMX
   SUMY=ZY1(IS)+SUMY
   SLMZ=ZV1(IS)+SUMZ
   SLMT=ZT1(IS)+SUMT
68 CCNTINUE
   AVE1=SLMX/144.
   AVE2=SUMY/144.
   AVE3=SUMZ/144.
   AVE4=SLMT/144.
   CC 69 IS=1,8192
   ZZX1(I4)=ZX1(IS)+(CCNSTX-AVE1)
   ZZY1(I4)=ZY1(IS)+(CCNSTY-AVE2)
   ZZV1(I4)=ZV1(IS)+(CCNSTZ-AVE3)
   ZZT1(I4)=ZT1(IS)+(CCNSTT-AVE4)
   I4=I4+1
69 CCNTINUE
37 CCNTINUE
   CC 91 I3=1,8192
   TIME2(I5)=(DELTAT*FLOAT(I3))+(128.0*FLOAT(K))
   I5=I5+1
91 CCNTINUE
   K=K+1
7C CCNTINLE
C     THE FCLLOWING LINES CF CODE PERFORMS A DOUBLE RLNNING PCINT
C     AVERAGE ON THE DATA.
   DO 73 L2=1,2
   Q=0
   DC 74 IS=1,65318
   SUMX=0.0
   SUMY=0.0
   SLMZ=0.0
   SUMT=0.0
   DC 75 J=1,144
   SLMX=ZZX1(Q+J)+SUMX
   SUMY=ZZY1(Q+J)+SUMY
   SLMZ=ZZV1(Q+J)+SUMZ
   SLMT=ZZT1(Q+J)+SUMT
75 CCNTINUE
   ZZX1(IS)=SLMX/144.
   ZZY1(IS)=SLMY/144.
   ZZV1(IS)=SUMZ/144.
   ZZT1(IS)=SLMT/144.
```

```
      Q=Q+1
   74 CONTINUE
   73 CONTINUE
C
C     VERSATEC PLOT OF B - MAGNETIC FIELD (SMOOTHED)
C
      NPTS=1020/DELTAT +1.
C       'NPTS' DETERMINES NUMBER OF POINTS NECESSARY IN ORDER FOR
C        THE 0 TO 2041  SECS RANGE TO BE PLOTTED.
C       FOR THE FOLLOWING 'ITB' AND 'RTB' VALUES REVIEW THE WRITE-UP
C       FOR THE SUBROUTINE PROCEDURE 'DRAWP'.
      ITB(3)=20
      ITB(4)=8
      ITB(7)=1
      ITB(12)=0
      RTB(1)=0.0
      RTB(2)=0.0
      RTB(3)=ALAE(1)
      READ(5,3000)TITLE
      CALL  DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)
      RTB(3)=ALAE(2)
      READ(5,3000)TITLE
      CALL  DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)
      RTB(3)=ALAE(3)
      READ(5,3000)TITLE
      CALL  DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
      ITB(12)=1
      RTB(3)=ALAB(4)
      READ(5,3000)TITLE
      CALL  DRAWP(NPTS,TIME2,ZZT1,ITB,RTB)
      ITB(3)=7
      ITB(4)=5
      ITB(12)=0
      RTB(3)=ALAE(1)
      READ(5,3000)TITLE
      CALL  DRAWP(NPTS,TIME2,ZZX1,ITB,RTB)
      RTB(3)=ALAE(2)
      READ(5,3000)TITLE
      CALL  DRAWP(NPTS,TIME2,ZZY1,ITB,RTB)
      RTB(3)=ALAE(3)
      READ(5,3000)TITLE
      CALL  DRAWP(NPTS,TIME2,ZZV1,ITB,RTB)
      ITB(12)=1
      RTB(3)=ALAE(4)
      READ(5,3000)TITLE
      CALL  DRAWP(NPTS,TIME2,ZZT1,ITB,RTB)
 3000 FORMAT(6A8)
      STOP
```

```
      END
      SUBROUTINE RD(IUN,IC,IRS,IREC,IRQ)
C
C        THIS PRCCEDURE FURNISHED BY DR. TIM STANTCN,
C        DEPARTMENT OF OCEANOGRAPHY.
C
C             READ DATA FROM IUN, ALLIGN , CHECK & RETURN
C
C      IUN=TAPE NUMBER, EG 20
C      IO=INTEGER*2 ARRAY, 16 LONG,(VALUES 0-4095, SLBTRACT 2048)*5
C              /2028.  GIVES VOLTAGE
C      IRS= NUMBER OF RESINCS ALLOWED (ERRORS)
C      IREC= COLNTER OF RECORDS (FRAMES CF DATA)
C          BLOCK 512 BITS,   32 BITS = RECORD
C          800 BPI TAPE UNLABLED
C      IRQ= NUMBER OF ACTLAL RESINCS (ERRORS)
C
C
      INTEGER * 2 IO(16),IP(16)
      CATA IRR /C/
      IF (IREC.EQ.0) IS=0
      IER=0
   20 FORMAT (16A2)
      IF (IS.NE.C) GO TO 50
      READ (IUN,20,END=90C) IP
      IREC=IREC+1
   40 IS=IS+1
      IF (IS.LT.17) GO TO 50
      READ (IUN,20,END=90C) IP
     IS=1
     IREC=IREC+1
   50 ICH=IMASK(IP(IS),3,0)+1
C     WRITE (6,55) ICH,IS,IUN,IREC
C  55 FORMAT ('  RESYNCING ICH,IS,IUN,IREC ',4I8)
C
     IF (ICH.NE.1) GO TO 40
     DC 100 I=1,16
      IO(I)=ISHIFT(IP(IS),4)
     ICH=IMASK(IF(IS),3,0)+1
     IF (ICH.EQ.I) GO TO 80
     IER=IER+1
     WRITE (6,7C)  IUN,IREC ,I,ICH,IER
   70 FORMAT (' UNIT ',I3,' RECORD ',I6,'CHAN & DATA CH ',2I4,
     $ 'ERRORS ',I7)
   80 IS=IS+1
      IF (IS.LT.17) GO TC 100
      READ (IUN,20,END=900) IP
      IS=1
```

```
      IREC=IREC+1                                                       LFV03370
  100 CONTINUE                                                          LFV03380
C                                                                       LFV03390
      IF (IER.EQ.0) GO TO 150                                           LFV03400
      IRR=IRR+1                                                         LFV03410
      IF (IRR.LT.IRS) GO TO 120                                         LFV03420
      WRITE (6,110)                                                     LFV03430
  110 FORMAT ('1 STOPPED IN SUB RD BECAUSE OF IRR.GT.',I6,' AT L110')   LFV03440
      IRQ=IRR                                                           LFV03450
      STOP                                                              LFV03460
  120 CONTINUE                                                          LFV03470
      WRITE (6,130) IREC,IRR                                            LFV03480
  130 FORMAT (' RESYNC AT FRAME ',I6,' WITH TOTAL ERRORS ',I7)          LFV03490
      IER=0                                                             LFV03500
      IRQ=IRR                                                           LFV03510
      GO TO 50                                                          LFV03520
  150 CONTINUE                                                          LFV03530
      RETURN                                                            LFV03540
  900 WRITE (6,910) IUN,IREC                                            LFV03550
  910 FORMAT ('1   END OF UNIT ',I3,' AT REC ',I7)                      LFV03560
      STOP                                                              LFV03570
      END                                                               LFV03580
      FUNCTION ISHIFT (IN,NPLC)                                         LFV03590
C             RETURNS SHIFTED VALUE OF I*2 WORD IN                      LFV03600
C             -VE LEFT,+VE RIGHT SHIFT                                  LFV03610
C                                                                       LFV03620
      INTEGER * 2 IN                                                    LFV03630
      IP=IN                                                             LFV03640
      IF (IP.LT.0) IP=IP+65536                                          LFV03650
      IF (NPLC.LT.0) GO TO 30                                           LFV03660
      ISHIFT=IP/(2**IABS(NPLC))                                         LFV03670
      RETURN                                                            LFV03680
   30 ISHIFT=IP*(2**IABS(NPLC))                                         LFV03690
      IF (ISHIFT.GT.65535) ISHIFT=MOD(ISHIFT,65536)                     LFV03700
      RETURN                                                            LFV03710
      END                                                               LFV03720
      FUNCTION IMASK (IN,IBL,IBR)                                       LFV03730
C             MASK I*2 WORD IN OUTSIDE BITS IBL & IBR                   LFV03740
C                                                                       LFV03750
      INTEGER * 2 IN,IO                                                 LFV03760
      IO=IN                                                             LFV03770
      IF (IBR.EQ.0) GO TO 50                                            LFV03780
      IT=ISHIFT(IN,IBR)                                                 LFV03790
      IO=IT                                                             LFV03800
   50 IP=ISHIFT(IO,IBL-15-IBR)                                          LFV03810
      IO=IP                                                             LFV03820
      IMASK=ISHIFT(IO,15-IBL)                                           LFV03830
      RETURN                                                            LFV03840
```

```
      END                                                  LFV03850
/*                                                         LFV03860
//GC.SYSIN DC *                                            LFV03870
LAMESA VILLAGE ,  4 AUG 83  1802-1819 LOCAL                LFV03880
X CCIL AMP IN NT                                           LFV03890
LAMESA VILLAGE ,  4 AUG 83, 1802-1819 LOCAL                LFV03900
Y COIL AMP IN NT                                           LFV03910
LAMESA VILLAGE ,  4 AUG 83, 1802-1819 LOCAL                LFV03920
Z CCIL AMP IN NT                                           LFV03930
LAMESA VILLAGE ,  4 AUG 83, 1802-1819 LOCAL                LFV03940
TCTAL FIELD  AMP IN NT                                     LFV03950
LAMESA VILLAGE ,  4 AUG 83, 1802-1819 LOCAL                LFV03960
X CCIL AMP IN NT                                           LFV03970
LAMESA VILLAGE ,  4 AUG 83, 1802-1819 LOCAL                LFV03980
Y COIL AMP IN NT                                           LFV03990
LAMESA VILLAGE ,  4 AUG 83, 1802-1819 LOCAL                LFV04000
Z COIL AMP IN NT                                           LFV04010
LAMESA VILLAGE ,  4 AUG 83, 1802-1819 LOCAL                LFV04020
TCTAL FIELD AMP IN NT                                      LFV04030
/*                                                         LFV04040
//GO.FT20F001 DD UNIT=3400-4,VOL=SER=LMDT3A,DISP=(CLC,KEEP),  LFV04050
//             LABEL=(1,NL,,IN),                           LFV04060
//             DCB=(RECFM=FB,LRECL=32,BLKSIZE=512,DEN=2)   LFV04070
//GO.SYSDUMP DD SYSOUT=A                                   LFV04080
/*                                                         LFV04090
//                                                         LFV04100
```

APPENDIX G

COHER COMPUTER PROGRAM

```
//COHER32 JOB (2992,0165),'ANTHONY   SMC 2123',CLASS=G
//*MAIN ORG=NPGVM1.2992P,LINES=(75)
//*FORMAT PR,DDNAME=PLOT.SYSVECTR,DEST=LOCAL
// EXEC FRTXCLGP,PARM.LKED='LIST,MAP,XREF',REGION.GO=2048K
//FORT.SYSIN DD DSN=MSS.SYS3.NONIMSL.SOURCE(FOURT),DISP=SHR
//     DD *
C        THIS PROGRAM READS IN DATA FROM DIGITAL TAPES USING THE
C     SUBROUTINE RD, NORMALIZES THE DATA BETWEEN -5 AND +5 VOLTS,
C     PERFORMS A FOURIER TRANSFORM ON THE DATA INTO FREQUENCY SPACE
C     AND THEN CALCULATES THE COHERENCE OF EACH INDIVIDUAL AXIS BETWEEN
C     THE LAMESA VILLAGE AND CHEW'S RIDGE SITES.
C
      INTEGER*2 IN(16)
C      ARRAY 'IN' IS USED IN READING DATA FROM TAPE
      COMPLEX*8 XXX(8192),YYY(8192),ZZZ(8192)
      COMPLEX*8 XXL(8192),YYL(8192),ZZL(8192)
      COMPLEX*8 XXC(8192),YYC(8192),ZZC(8192)
      DIMENSION CTLX(8192),CTLY(8192),CTLZ(8192)
      DIMENSION CTCX(8192),CTCY(8192),CTCZ(8192)
      DIMENSION CTLCX(8192),CTLCY(8192),CTLCZ(8192)
      DIMENSION COHLCX(8192),COHLCY(8192),COHLCZ(8192)
C      COMPLEX*8 ARRAYS ARE USED BECAUSE COMPLEX NUMBERS ARE REQUIRED
C      BY THE FOURIER TRANSFORM SUBROUTINE 'FOURT'.
      DATA CTLX,CTLY,CTLZ/24576*0./
      DATA CTCX,CTCY,CTCZ/24576*0./
      DATA CTLCX,CTLCY,CTLCZ/24576*0./
      DATA COHLCX,COHLCY,COHLCZ/24576*0./
      DIMENSION FREQ(8192),FRQ2(8192),WORK(16384)
      INTEGER*4 ITB(12)/12*0/
      REAL*4    RTB(28)/28*0.0/
      REAL ALAB(4)/'COHX','COHY','COHZ','TOT'/
      REAL*8 TITLE(12)
      EQUIVALENCE(TITLE(1),RTB(5))
C      ARRAYS 'ITB','RTB','ALAB',AND 'TITLE' ARE USED IN GENERATING
C      THE VERTSATEC PLOTTER OUTPUT.
C    THE FOLLOWING LOOP ADVANCES THE DIGITAL TAPE BY ISEC SECONDS.
C
      ISEC=200
      ITL=ISEC*64
      DO 55 JJ=1,ITL
      CALL RD(20,IN,200,IREC,IRR)
   55 CONTINUE
      NR=19
      FNR=FLOAT(NR)
      DO 70 LI=1,NR
C      THE DO LOOP ENDING WITH STATEMENT 70 ENABLES THE PROGRAM TO
C      PROCESS A LARGE AMOUNT OF DATA BY REPEATING THE PROCESS IN
C      BLOCKS.
```

```
C        'NR' REPRESENTS THE NUMBER OF DATA SEQUENCES.
C        1 SEQUENCE CURRENTLY EQUALS 8192 DATA POINTS FOR EACH CHANNEL
C        OR 128 SECONDS OF DATA.
C
C         THE DO LOOP ENDING WITH 60 READS THE DATA FROM THE PCM FRAME,
C         STRIPS OUT THE SYNC CODE, AND SORTS OUT THE DATA BY COIL
C         CHANNEL. FIRST, THE NEXT THREE STATEMENTS READS THE DATA
C         FROM THE LAMESA SITE THAT WAS PREVIOUSLY STORED IN THE
C         IBM 3033 MASS STORAGE SYSTEM.
      READ(21) XXX
      READ(21) YYY
      READ(21) ZZZ
C        SET THE IMAGINARY PART OF THE COMPLEX NUMBERS EQUAL TO ZERO.
      DO 43 I=1,8192
      XXL(I)=REAL(XXX(I))
      YYL(I)=REAL(YYY(I))
      ZZL(I)=REAL(ZZZ(I))
   43 CONTINUE
C        NOW READ THE CHEW'S RIDGE DATA FROM THE COMPUTER TAPE.
      DO 60 JJ=1,8192
      CALL RD(20,IN,1000,IREC,IRR)
      XXC(JJ)=IN(2)
      YYC(JJ)=IN(3)
      ZZC(JJ)=IN(4)
   60 CONTINUE
      N=8192
      FN=FLOAT(N)
      DELTAT=1./64.
      T=FN*DELTAT
      DELTAF=1./T
C     NORMALIZE THE CHEW'S RIDGE DATA BETWEEN +5 AND -5 VOLTS AND SET
C        THE IMAGINARY PART EQUAL TO ZERO. THE LAMESA VILLAGE DATA HAS
C        ALREADY BEEN NORMALIZED IN THE MASS STORAGE PROGRAM.
      DO 20 J=1,8192
      XXC(J)=((XXC(J)-2048.)*5./2048.)
      XXC(J)=REAL(XXC(J))
      YYC(J)=((YYC(J)-2048.)*5./2048.)
      YYC(J)=REAL(YYC(J))
      ZZC(J)=((ZZC(J)-2048.)*5./2048.)
      ZZC(J)=REAL(ZZC(J))
   20 CONTINUE
C        TRANSFORM THE DATA FROM ALL THREE COILS AT BOTH SITES INTO THE
C        FREQUENCY DOMAIN.
      CALL FOURT(XXL,N,1,-1,0,WORK)
      CALL FOURT(YYL,N,1,-1,0,WORK)
      CALL FOURT(ZZL,N,1,-1,0,WORK)
      CALL FOURT(XXC,N,1,-1,0,WORK)
      CALL FOURT(YYC,N,1,-1,0,WORK)
```

```
      CALL FOURT(ZZC,N,1,-1,0,WORK)
C      THE NEXT LCOP IS REQUIRED AFTER TRANSFORMATICN. SEE THE WRITEUP
C      FOR THE SUBROUTINE 'FOURT'.
      DO 40 K4=1,N
      XXL(K4)=XXL(K4)/FN
      YYL(K4)=YYL(K4)/FN
      ZZL(K4)=ZZL(K4)/FN
      XXC(K4)=XXC(K4)/FN
      YYC(K4)=YYC(K4)/FN
      ZZC(K4)=ZZC(K4)/FN
   40 CONTINUE
C      THE NEXT LOOP SUMS EACH DATA SAMPLE OVER THE NR BLOCKS OF
C      DATA.
      DO 30 II=1,N
      CTLX(II)=CTLX(II)+CABS(XXL(II)*CONJG(XXL(II)))
      CTLY(II)=CTLY(II)+CABS(YYL(II)*CONJG(YYL(II)))
      CTLZ(II)=CTLZ(II)+CABS(ZZL(II)*CONJG(ZZL(II)))
      CTCX(II)=CTCX(II)+CABS(XXC(II)*CONJG(XXC(II)))
      CTCY(II)=CTCY(II)+CABS(YYC(II)*CONJG(YYC(II)))
      CTCZ(II)=CTCZ(II)+CABS(ZZC(II)*CONJG(ZZC(II)))
      CTLCX(II)=CTLCX(II)+CABS(XXL(II)*CONJG(XXC(II)))
      CTLCY(II)=CTLCY(II)+CABS(YYL(II)*CONJG(YYC(II)))
      CTLCZ(II)=CTLCZ(II)+CABS(ZZL(II)*CONJG(ZZC(II)))
   30 CONTINUE
C      NOW GO BACK AND GET THE NEXT BLOCK OF DATA AND PERFORM THE SAME
       ANALYSIS ON IT.
   70 CONTINUE
C      CALCULATE THE COHERENCE OF EACH COIL AND THE FREQUENCY SCALE
C      (LOG) IT IS PLOTTED AGAINST.
      DO 44 I4=1,N
      COHLCX(I4)=CTLCX(I4)/(SQRT(CTLX(I4))*SQRT(CTCX(I4)))
      COHLCY(I4)=CTLCY(I4)/(SQRT(CTLY(I4))*SQRT(CTCY(I4)))
      COHLCZ(I4)=CTLCZ(I4)/(SQRT(CTLZ(I4))*SQRT(CTCZ(I4)))
      FREQ(I4)=DELTAF*FLOAT(I4)
      FRQ2(I4)=ALOG10(FREQ(I4))
   44 CONTINUE
C
C
      NPTS=1./DELTAF +1.
C        'NPTS' DETERMINES NUMBER OF POINTS NECESSARY IN ORDER FOR
C         THE 0 TO NPTS  FREQUENCY RANGE TO BE PLOTTED.
C       FOR THE FOLLOWING 'ITB' AND 'RTB' VALUES REVIEW THE WRITE-UP
C       FOR THE SUBROUTINE PROCEDURE 'DRAWP'.
      ITB(3)=20
      ITB(4)=8
      ITB(7)=1
      ITB(12)=0
      RTB(1)=0.0
```

```
      RTB(2)=0.0
      RTB(3)=ALAE(1)
      READ(5,300C)TITLE
      CALL  DRAWP(NPTS,FRQ2,COHLCX,ITB,RTB)
      RTB(3)=ALAE(2)
      READ(5,300C)TITLE
      CALL  DRAWP(NPTS,FRQ2,COHLCY,ITB,RTB)
      RTB(3)=ALAE(3)
      READ(5,300C)TITLE
      CALL  DRAWP(NPTS,FRQ2,COHLCZ,ITB,RTB)
      ITB(3)=7
      ITB(4)=5
      ITB(12)=0
      RTB(3)=ALAE(1)
      READ(5,300C)TITLE
      CALL  DRAWP(NPTS,FRQ2,COHLCX,ITB,RTB)
      RTB(3)=ALAE(2)
      READ(5,3000)TITLE
      CALL  DRAWP(NPTS,FRQ2,CCHLCY,ITB,RTB)
      RTB(3)=ALAE(3)
      READ(5,3000)TITLE
      CALL  DRAWP(NPTS,FRQ2,CCHLCZ,ITB,RTB)
 3000 FCRMAT(6A8)
      STOP
      END
       SUBROUTINE RD(IUN,IC,IRS,IREC,IRQ)
C
C         THIS PROCEDURE FURNISHED BY DR. TIM STANTCN,
C         DEPARTMENT OF OCEANOGRAPHY.
C
C              READ DATA FROM IUN, ALLIGN , CHECK & RETURN
C
C       IUN=TAPE NUMBER, EG 20
C       IO=INTEGER*2 ARRAY, 16 LONG,(VALUES 0-4095, SUBTRACT 2048)*5
C                /2028.   GIVES VOLTAGE
C       IRS= NUMBER OF RESINCS ALLOWED (ERRORS)
C       IREC= COUNTER OF RECORDS (FRAMES CF DATA)
C           BLOCK 512 BITS,   32 BITS = RECORD
C           800 BPI TAPE UNLABLED
C       IRQ= NUMEER OF ACTUAL RESINCS (ERRORS)
C
C
       INTEGER * 2 IO(16),IP(16)
       CATA IRR /C/
       IF (IREC.EQ.0) IS=0
       IER=0
 20    FORMAT (16A2)
       IF (IS.NE.0) GO TO 50
```

```
      READ (IUN,20,END=9CC) IP                                          COHO1930
       IREC=IREC+1                                                      COHO1940
 40    IS=IS+1                                                          COHO1950
       IF (IS.LT.17) GO TO 50                                           COHO1960
       READ (IUN,20,END=9CC) IP                                         COHO1970
      IS=1                                                              COHO1980
      IREC=IREC+1                                                       COHO1990
 50   ICH=IMASK(IP(IS),3,0)+1                                           COHO2000
C      WRITE (6,55) ICH,IS,IUN,IREC                                     COHO2010
 55    FORMAT ('  RESYNCING ICH,IS,IUN,IREC ',4I8)                      COHO2020
C                                                                       COHO2030
      IF (ICH.NE.1) GO TO 40                                            COHO2040
      DC 100 I=1,16                                                     COHO2050
       IO(I)=ISHIFT(IP(IS),4)                                           COHO2060
      ICH=IMASK(IP(IS),3,0)+1                                           COHO2070
      IF (ICH.EQ.1) GO TO 80                                            COHO2080
      IER=IER+1                                                         COHO2090
      WRITE (6,7C)  IUN,IREC ,I,ICH,IER                                 COHO2100
 70    FORMAT (' UNIT ',I3,' RECORD ',I6,'CHAN & DATA CH ',2I4,         COHO2110
     $ 'ERRORS ',I7)                                                    COHO2120
 80    IS=IS+1                                                          COHO2130
       IF (IS.LT.17) GO TO 100                                          COHO2140
       READ (IUN,20,END=9CC) IP                                         COHO2150
       IS=1                                                             COHO2160
       IREC=IREC+1                                                      COHO2170
 100   CONTINUE                                                         COHO2180
C                                                                       COHO2190
       IF (IER.EC.0) GO TO 150                                          COHO2200
       IRR=IRR+1                                                        COHO2210
       IF (IRR.LT.IRS) GO TO 120                                        COHO2220
       WRITE (6,110)                                                    COHO2230
 110   FORMAT ('1 STOPPED IN SUB RD BECAUSE OF IRR.GT.',I6,' AT L110')  COHO2240
       IRQ=IRR                                                          COHO2250
       STOP                                                             COHO2260
 120   CONTINUE                                                         COHO2270
       WRITE (6,130) IREC,IRR                                           COHO2280
 130   FORMAT (' RESYNC AT FRAME ',I6,' WITH TOTAL ERRORS ',I7)         COHO2290
       IER=0                                                            COHO2300
       IRQ=IRR                                                          COHO2310
       GO TO 50                                                         COHO2320
 150   CONTINUE                                                         COHO2330
       RETURN                                                           COHO2340
 900   WRITE (6,910) IUN,IREC                                           COHO2350
 910   FORMAT ('1   END OF UNIT ',I3,' AT REC ',I7)                     COHO2360
       STOP                                                             COHO2370
       END                                                              COHO2380
C                                                                       COHO2390
       FUNCTION ISHIFT (IN,NPLC)                                        COHO2400
```

```
C                    RETURNS SHIFTED VALUE OF I*2 WORD IN
C                    -VE LEFT,+VE RIGHT SHIFT
C
      INTEGER * 2 IN
      IP=IN
      IF (IP.LT.0) IP=IP+65536
      IF (NPLC.LT.0) GO TO 30
      ISHIFT=IP/(2**IABS(NPLC))
      RETURN
 30   ISHIFT=IP*(2**IABS(NPLC))
      IF (ISHIFT.GT.65535) ISHIFT=MOD(ISHIFT,65536)
      RETURN
      END
      FUNCTION IMASK ( IN,IBL,IBR)
C                    MASK I*2 WORD IN OUTSIDE BITS IBL & IBR
C
      INTEGER * 2 IN,IC
      IO=IN
      IF (IBR.EQ.0) GO TO 50
      IT=ISHIFT(IN,IBR)
      IO=IT
 50   IP=ISHIFT(IO,IBL-15-IBR)
      IO=IP
      IMASK=ISHIFT(IO,15-IBL)
      RETURN
      END
/*
//GO.SYSIN DD *
LAMESA-CHEW'S RIDGE,4 AUG 83, 1700-1740 LOCAL
X COIL COHERENCE
LAMESA-CHEW'S RIDGE,4 AUG 83, 1700-1740 LOCAL
Y COIL COHERENCE
LAMESA-CHEW'S RIDGE,4 AUG 83, 1700-1740 LOCAL
Z COIL COHERENCE
LAMESA-CHEW'S RIDGE, 4 AUG 83, 1700-1740 LOCAL
X COIL COHERENCE
LAMESA-CHEW'S RIDGE,4 AUG 83,  1700-1740 LOCAL
Y COIL COHERENCE
LAMESA-CHEW'S RIDGE,4 AUG 83,  1700-1740 LOCAL
Z COIL COHERENCE
/*
//GO.FT20F001 DD UNIT=3400-4,VOL=SER=CRDT3,DISP=(OLD,KEEP),
//             LABEL=(1,NL,,IN),
//             DCB=(RECFM=FB,LRECL=32,BLKSIZE=512,DEN=2)
//GO.FT21F001 DD UNIT=3330V,MSVGP=PUB4A,DISP=(OLD,KEEP),
//             DSN=MSS.S2992.LMDT3D,
//             DCB=(RECFM=VBS,BLKSIZE=4096,LRECL=4092)
//GO.SYSDUMP DD SYSOUT=A
```

```
/*                                                                      COHO2890
//                                                                      COHO2900
```

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Anthony
Coherence study of geomagnetic fluctuations in frequency range .04 - 0.6 Hz between remote land sites.